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CONTROL OF INDUSTRIAL WASTES IN MUNICIPALITIES

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COURSE COMMITTEE: N. A. Gillies
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SEWAGE TREATMENT PLANT

Many people are quite familiar with the processes of sewage treatment, but it is probably true that while having a general knowledge of the principles involved, most have lost sight of the actual details of these processes. Since everything in this course is designed to help those involved to ensure that the sewage treatment plant and the processes carried on within it are not adversely affected by any material discharged into the sewers, it is important, even for those who are totally familiar with sewage treatment, to have the processes firmly and freshly in mind before proceeding to the remainder of the course. A very brief, non-technical review of the major steps in conventional treatment of sewage is therefore in order.

It is often said of sewage treatment that there are three kinds; primary, secondary and tertiary. However, it is preferable to look at those merely as successive stages of a single type of treatment. Consider each stage in turn:

Primary Treatment

Primary treatment may be considered a mechanical stage. That is, the operations carried out are designed basically to remove suspended solid materials from

the water and may include coarse screening to remove large material, grit settling to remove heavy inorganic matter, comminution (shredding) to break down the remaining suspended solids. The clarified liquid from the settling step is then passed on for further treatment or, in the case of a plant providing only primary treatment, is disinfected and discharged to the receiving watercourse. Figure I shows schematically the series of operations and in addition shows the usual method of handling the sludge drawn from the clarifier.

Sludge digestion is an ancillary step which is not strictly essential to the sewage treatment process, but it does provide further desirable treatment. Primarily, digestion reduces the volume of sludge to be disposed of but it also renders the solids hygenically more acceptable. In fact, digestion may be considered as "secondary treatment" for the solid portion of the sewage. Briefly, the raw sludge is fed into a tank known as a digester where it is acted upon by micro-organisms which partially degrade the material. The most common type of digestion process has been an-aerobic, although aerobic digestion is becoming more common.

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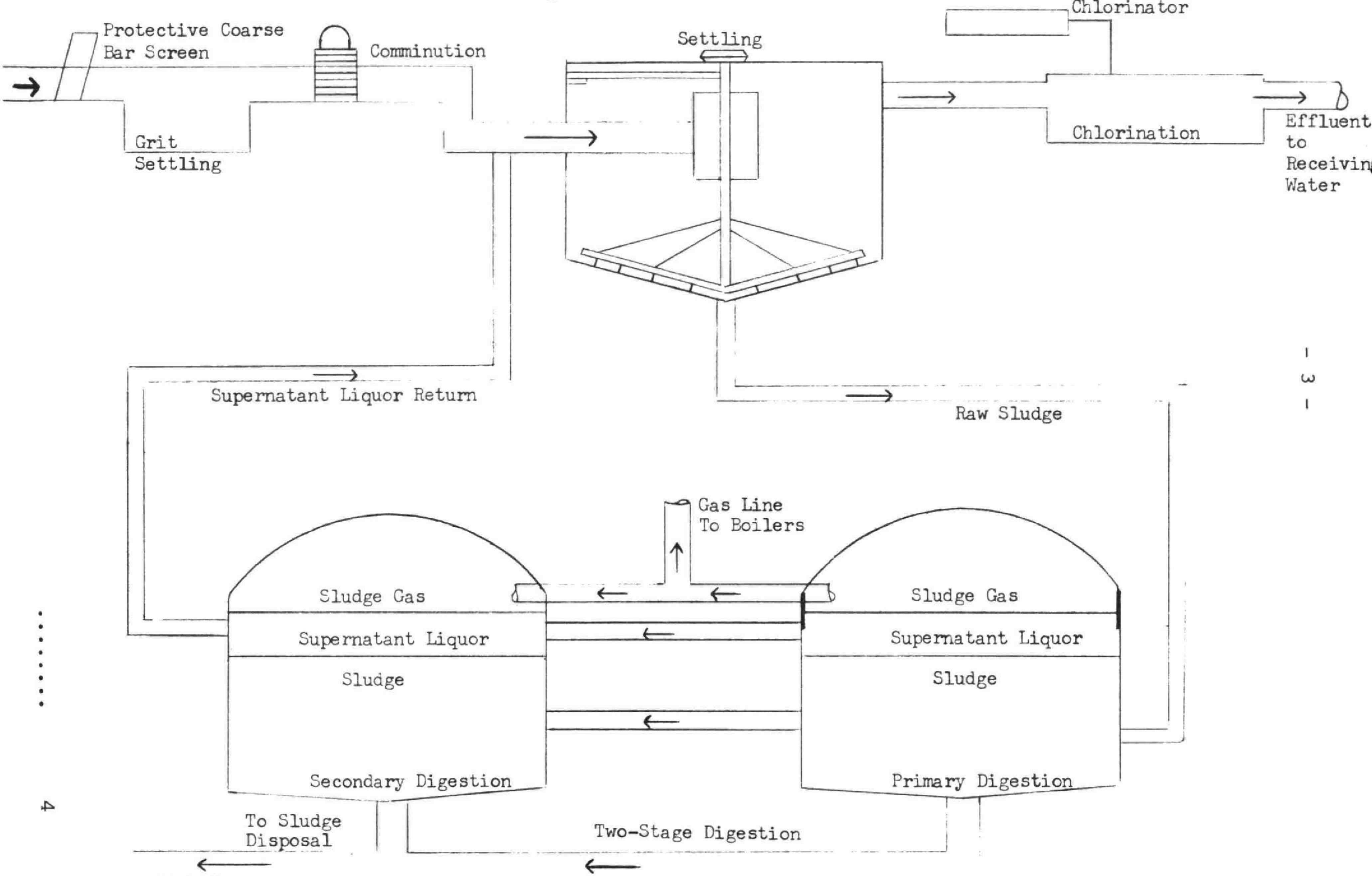
FIGURE I

PRIMARY SEWAGE TREATMENT



In anaerobic digestion, a closed tank is used and the micro-organisms function in the absence of free oxygen, hence the name anaerobic. The temperature in the digester is controlled between 90-95°F to provide the most suitable environment for the micro-organisms to feed upon the organic material. Gas is produced which contains 60-75% methane, 15-30% carbon dioxide, 1-10% nitrogen and small quantities of such substances as hydrogen, oxygen and hydrogen sulphide. The gas has a heat value of some 600 - 700 BTU per cubic foot and is suitable therefore as a fuel for the sewage plant boilers. Excess gas may be burned as wastes. The supernatant liquor in the digester may be drawn off and returned to the settling section of the plant.

In aerobic digestion the sludge is mixed and air is passed through it. The micro-organisms in this case require the presence of free oxygen to enable them to feed upon the organic material. The sludge produced is similar to that from anaerobic digestion.

In either case, some form of dewatering normally is carried out prior to final disposal. Methods used may include centrifuging, elutriation, vacuum filtration

or air drying. Land dumping is a common method of disposal, but incineration is also practised.

Secondary Treatment

Secondary treatment includes steps in addition to those of primary treatment and normally involves breakdown of the waste into simpler substances by the action of living organisms. One of the most commonly used systems is the Activated-Sludge Process and it is this which I will use as an example. The waste from primary treatment enters the aeration section where air is bubbled through it. The oxygen thus supplied is used by the micro-organisms which are present to degrade the organic matter in the sewage. Since they require free oxygen, the micro-organisms are known as aerobes and they use the organic portion as food, producing simpler substances and resulting in a waste having a very much reduced potential to pollute. The effluent from the aeration section passes to the settling section where the biological material is allowed to settle out. The clarified effluent is then disinfected and discharged to the receiving watercourse. The solid material which collects in the settling section is known as activated sludge and since it is composed of living biological material, it may be reused to treat more sewage. It is therefore returned

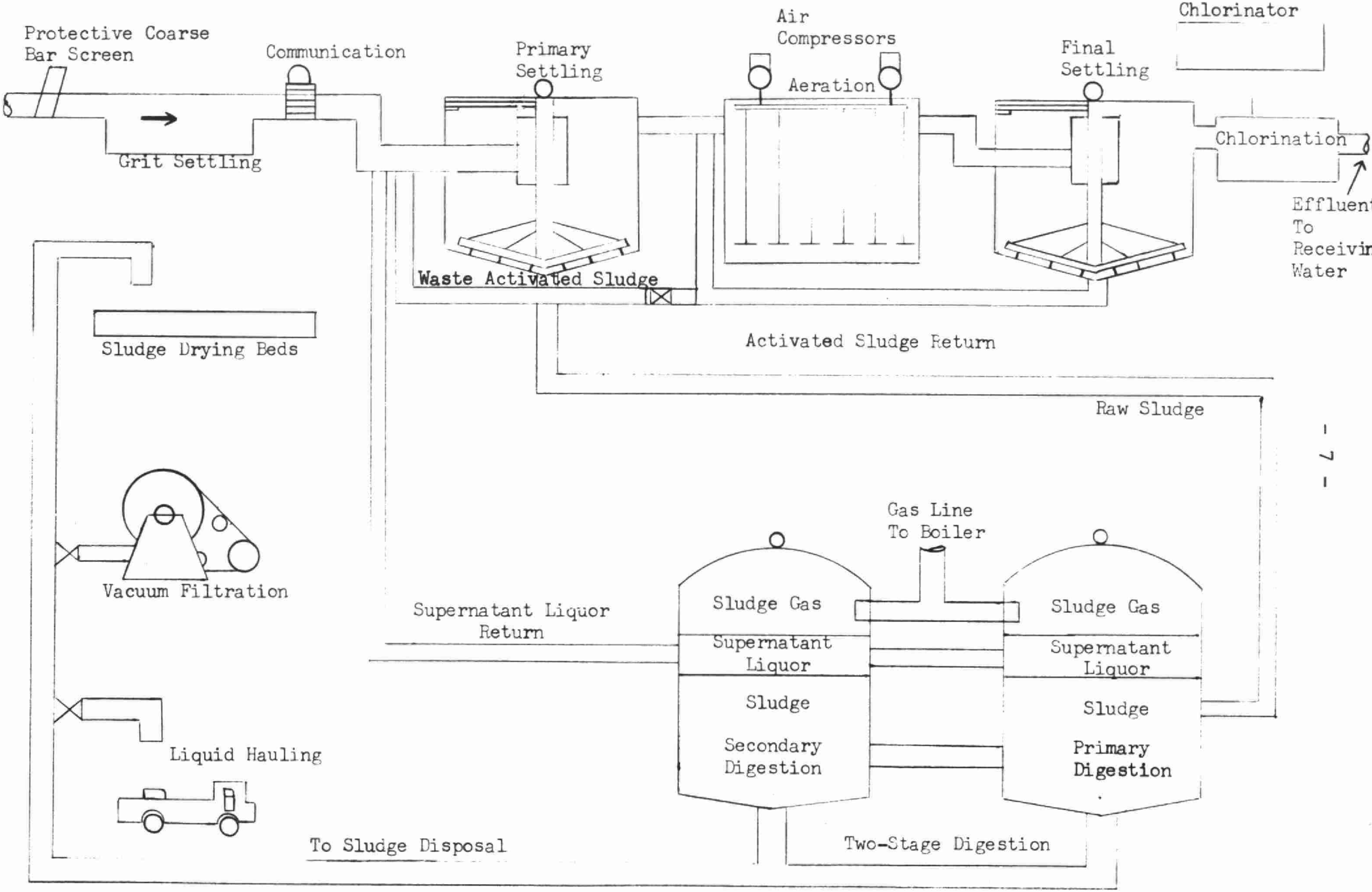
from the settling section to the influent of the aeration section, but since the bacteria are constantly growing and multiplying, a portion of the sludge must be discarded so that the amount in the system remains at a desired level (constant food/micro-organism ratio). The waste activated sludge is usually fed to the settling section of the primary treatment, from where it proceeds to digestion and disposal as previously noted.
Figure II shows schematically the primary and secondary (activated sludge) stages. There are, of course, other types of secondary treatment and these include, contact stabilization, aerated lagoon, trickling filter, oxidation ditch, etc., but these differ from the activated sludge system only in the method by which treatment is effected. The basic process whereby the waste is used as food by microbes remains the same.

Tertiary Treatment

Tertiary treatment cannot be described in quite such straightforward terms as the primary and secondary stages, since there are many different processes and none as yet has become conventional practice. While the objectives of the other stages are removal of solids, removal of organic material and disinfection, tertiary treatment has many different objectives including removal of very fine solid matter and removal of

FIGURE II

SECONDARY SEWAGE TREATMENT (ACTIVATED SLUDGE)



phosphorus, nitrogen, taste and odour causing components, dissolved solids, etc. The precise nature of the treatment step will depend upon the desired objective, but will involve physical/chemical processes such as chemical interaction and precipitation, reverse osmosis, carbon adsorption, filtration, etc. These processes will be described later in the course.

To summarize, primary treatment removes some of the solids and some of the organic materials. Secondary treatment removes most of the remaining solids and most of the remaining organic material. Tertiary treatment removes such remaining contaminants necessary to ensure an acceptable effluent. Disinfection of the effluent prior to final discharge is normally practised and chlorine gas is normally used for this purpose.

As already noted, this presentation is intended only to focus briefly and non-technically on the processes which the remainder of this course, it is hoped, will equip those taking the course to protect. To become more familiar with the technical details of sewage treatment, there are several works of reference which would be of value and a list of these may be found in the appendix.

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GENERAL CHARACTERISTICS

AND

PROBLEMS OF INDUSTRIAL WASTES

INTRODUCTION

The purpose of this paper is to cover effluent characteristics and the different parameters that are used to permit one to assign numbers to these characteristics. An attempt will also be made to discuss the effluent of these various pollutants on the proper operation of a sewage treatment plant and on a watercourse should these materials be released without prior treatment.

Contaminants in a waste may be divided into two general groups being either in suspension or dissolved in the effluent. Treatment plants are normally designed to remove solids first and then provide a second set of facilities to handle the dissolved components. To simplify this discussion the parameters will follow this general division of materials in suspension and in solution. The waste characteristics and parameters will therefore be divided into solids, and other more specific components in solution such as metals, cyanides, etc.. Greases, oils and colour will be handled as miscellaneous parameters.

SOLIDS

Solids in a waste can be subdivided into suspended

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solids and dissolved solids. A suspended solid is normally considered as being particulate matter entrained in the waste and varying in size from a small particle measured in the micron range, to larger particles such as wood fibre from the pulp and paper industry, fruit and vegetable particles from the canning industry, salt and sand from gravel washing operations, etc. Dissolved solids is a general term which takes into account all materials held in solution.

To determine the amount of solids contained in the waste by the laboratory, an aliquot of waste is taken from the sample bottle and filtered under controlled conditions. The particulate matter caught and left on the filter paper is the suspended solid. The liquid which passed through the filter paper is evaporated, again under controlled conditions, and the material remaining in the crucible after evaporation is taken as being dissolved solids. The sum of the suspended solids and dissolved solids represents the total solids contained in the waste. All concentrations are recorded in milligrams per litre or parts per million.

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Suspended Solids

Suspended solids may be further divided into settleable solids and non-settleable solids. To differentiate between the two is difficult because these two terms have already been confused in literature. Strictly speaking all solids before they settle out either in a watercourse or in a laboratory bottle are suspended solids. The amount that would settle out depends upon quiescence, temperature, density, and many other factors. For this paper little differential will be made between these two types since their effects are almost the same. Settleable solids and the rate of settling are of significance when designing treatment systems that remove solids by sedimentation. The size of the treatment facilities is then dependent upon the settling rates of the entrained matter.

Wastes containing excessive amounts of suspended solids and discharged to the watercourse can kill fish by simple abrasive action, and by clogging gills and other vital respiratory passages. Blanketing a stream or lake bottom, the material can destroy benthal organisms, roe and ruin spawning beds. A heavy discharge of suspended solids can cause turbidity and prevent the passage of sunlight necessary for

healthy vegetation growth. Treatment is therefore necessary to remove suspended solids from a waste discharge.

Suspended solids can also cause serious problems at sewage treatment plants. Abrasive materials can wear out sewers, piping, and pumps causing extensive maintenance problems. A heavy suspended material that can settle out readily and set up hard on the bottom of clarifiers can play havoc with the rake mechanism. Also too many solids in the primaries simply adds to the operators solids handling problems.

If an excessive amount of suspended solids which are readily biodegraded are introduced to a secondary treatment system, they may be tied up with biological floc and settle out prematurely in more quiescent corners of the aeration chamber and begin to turn septic. Solids settling out in municipal lagoons can use up capacity requiring more frequent clean-outs.

A secondary treatment system requires that some sludge be returned from the clarifier to the aeration facilities. If this sludge contains a high percentage of inert suspended solids, insufficient active sludge

may be recycled upsetting the proper operation of the secondary stage. Sludge recycle rates have to be manipulated which becomes one more additional operation that the operator must carry out to have his plant run effectively.

Dissolved Solids

The term dissolved solids is normally considered to include components dissolved in a waste such as carbonates, bicarbonates, chlorides, sulphates, calcium, magnesium, sodium, and potassium. Normally these materials are not serious pollutants in themselves however if their total concentration is high, then some problems may result. This general term can also include dissolved metals and toxic organic compounds however these materials are discussed individually since they show specific adverse effects at low concentrations.

Dissolved solids can create problems in a watercourse if discharged in excessive concentrations. Some solids can impart a taste and odour to the water rendering it unfit for human consumption. High dissolved solids concentrations have the ability to alter osmotic pressure which can create stresses in microscopic aquatic mechanisms resulting for instance in ruptures

to cell membranes.

Dissolved solids, except under extreme cases have little or no effect on proper sewage treatment plant operation. High chloride concentrations have been discharged to a sewage treatment plant without any apparent adverse affects. It is conceivable that high concentrations of dissolved solids fluctuating extremely can contribute to shock load effects. These occurrences are however somewhat infrequent.

COMPONENTS IN SOLUTION

Biological Oxygen Demand (BOD)

Biological oxygen demand denoted by the term BOD represents the quantity of material that will oxidize under biological influences. The BOD concentration does not reveal the concentration of a specific substance instead it measures the effect of a combination of substance and conditions.

An oxygen demand in a waste can be exerted by:

- carbonaceous organic material useable as a source of food by aerobic organisms.
- oxidizable nitrogen derived from nitrate, ammonia, and organic nitrogen compounds which can serve as food for bacteria.

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- certain chemical reducing compounds which normally are associated with industrial waste discharges.

When one of the above compounds is placed in water, in time it will be oxidized by bacteria and in so doing will use up the dissolved oxygen. In more simple terms, the amount of oxygen this material will consume is a measure of the BOD. Since more oxygen will be consumed the longer this material remains in the water, for the sake of uniformity it is necessary to specify a length of time. The length of time has been more or less arbitrarily set at 5 days and hence the more exact term is 5-day BOD.

In the laboratory BOD is determined by taking a sample of waste and diluting it to various concentrations with appropriate amounts of oxygen saturated distilled water which has been earlier seeded with bacteria (normally from an activated sludge plant). Diluted samples are made in duplicate so that one set of samples can be incubated at $20^{o}C$ for 5 days and the other set can be analysed immediately for dissolved oxygen. After 5 days the incubated samples are analysed for dissolved oxygen and the difference in the oxygen contents become

a measure of the biological oxygen demand of the waste. The above description of course is an oversimplification of a complex test.

To be an effective parameter the BOD concentration should be interpreted prior to use. If there is a toxic constituent in the waste, this may reduce biological activity during the incubation period and hence a low BOD concentration may be determined at the end. Some wastes are not readily biodegraded in the 5 day period requiring a longer incubation period and so a low BOD concentration would be obtained after a 5-day test. Thenature of the waste must be known to some extent before the BOD figure can be used effectively.

As a parameter the detrimental effects of organic matter on a watercourse, 5-day BOD in itself is not very meaningful since BOD is not a pollutant and causes no direct harm. The only time BOD is meaningful is if the dissolved oxygen content in the watercourse is reduced below levels that can sustain biological life. If natural re-aeration of streams exceeds oxygen consumption rates due to BOD, then pollution effects are minimal.

Large quantities of BOD are significant since they can produce septicity or decrease oxygen levels to the point where the water cannot sustain a biological community. In lakes or slow moving streams septic conditions can lead to turbidity, odour problems, and general unsightly conditions. The discharge of BOD material to a watercourse must therefore be controlled.

The BOD parameter is very essential to a sewage plant operator since this becomes one of the more important control parameters. One of the main objects of a sewage treatment plant is to stabilize the waste and this in effect means removing all or most of the materials exerting a BOD. By doing BOD analyses at various process stages at the sewage treatment plant, the operator can evaluate the operation of his plant. The amount of BOD requiring stabilization dictates the size of the aeration basin, sets out the amount of oxygen that must be supplied to the waste, limits feed rate, establishes sludge recycle rates, etc.

High quantities of materials exerting a BOD discharged to a sewer can overtax existing aeration facilities at a sewage treatment plant. If insufficient oxygen is provided, it will not be possible to maintain a proper dissolved oxygen in the overflow. The higher

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loading may affect sludge characteristics producing a poorly settleable sludge. Only partial treatment of wastes may occur resulting in a poor quality effluent released to the watercourse.

Chemical Oxygen Demand (COD)

It is quite obvious that the BOD test cannot be used for on the spot checks since it takes 5 days to carry out the test. The parameter COD represents the amount of oxygen required to chemically stabilize a waste. Similar to BOD the parameter measures the effects of a combination of materials and does not reveal the concentration of a specific substance.

In the laboratory COD is determined by taking an aliquot of the waste and boiling this waste in known amounts of chromic and sulphuric acid. Excess chromate is titrated and the COD value is related to the amount of dichromate consumed.

If BOD and COD relationships in a waste have been previously determined, it would be possible to perform COD analyses, estimate BOD concentrations, and check on the operation of the treatment system. It should be noted that COD tests can exclude some organic compounds in the waste which could exert a BOD (i.e.

acetic acid). On the other hand because chemical oxidation is more severe than biological oxidation, the laboratory preparation may oxidize such items as cellulose which is not readily oxidized biologically. The COD test should therefore be used with discretion with good interpretation of results.

Metals

Metals are found in wastes in solution as ions or in suspension as insoluble hydroxides or insoluble salts. Although metals are included in earlier parameters such as suspended and dissolved solids, it is best to discuss them separately on an individual basis because they are normally very toxic and special treatment systems have to be designed to remove them from the waste.

Metals are normally introduced to a watercourse as a result of an industrial waste discharge. In some cases natural leaching of a metal into a watercourse may occur if there are exposed ore bodies that can be worked upon by natural elements such as rain, frost, erosion, etc. For the most purposes if metals are present in a sanitary sewer, it is the result of an industrial waste discharge.

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Metals in solution require special consideration since they are extremely toxic both to biological life in a watercourse and to bacterial sludge necessary in sewage treatment plant operation. Because of their toxicity metals have been responsible for numerous fish kills in the province. Metals also have the ability to exhibit synergistic effects that is one metal can enhance the toxicity of another such that their combined concentration is more lethal than if one metal were found in a watercourse by itself.

Metals can also disrupt the proper operation of a sewage treatment plant. In extreme cases bacteria making up the biological system may be killed off entirely. At lower levels, metals may be picked up by bacterial sludge and may accumulate in the digester to toxic levels where the digester could no longer function.

Some of the more common metals found in wastes may be summarized in Table A.

Organic Compounds

There are also a number of organic compounds in solution that require special attention because they exhibit their own peculiar traits. Many of these compounds are

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TABLE A

COMMON METALS FOUND IN INDUSTRIAL WASTES

METAL	AFFECT ON WATERCOURSE	AFFECT ON SEWAGE TREATMENT PLANT	COMMENTS
CHROMIUM	Toxic to fish in concentrations from 5 ppm to 10 ppm	Toxic to biological sludge in concentration in excess of 10 ppm	Found in hexavalent and trivalent state
COPPER	Toxic range to fish is 0.1 ppm to 1 ppm	Toxic to biological sludge	Exhibits synergistic affects with zinc
IRON	Toxic range to fish is 0.2 ppm to 2 ppm	Less toxic to biological sludge	Easily forms hydroxide and settles out in primary treatment works
LEAD	Toxic range to fish is 0.1 ppm to 5 ppm	Toxic to bacterial sludge	Metal can accumulate in fish tissue
NICKEL	Less toxic to fish than other metals at concentrations in excess of 20 ppm	Less toxic to bacterial sludge	Forms complex with cyanide
ZINC	Toxic range to fish is 0.1 ppm to 1.0 ppm	Toxic to bacterial sludge	Exhibits synergistic affects with copper

also very toxic and hence they are discussed under separate headings.

Phenol

Phenol is a colorless crystalline substance with a characteristic medicinal type odour. It is used as a disinfectant and in the manufacture of various plastic type resins. It is very soluble in water and as a result can become a serious contaminant.

Phenol in domestic waters can cause a serious nuisance problem. During the chlorination of drinking water, phenols also become chlorinated, and even at extremely low concentrations (0.002 mg/l) give off an objectionable odour. This odour could and has upset many operations at breweries, distilleries, and soft drink bottling plants.

Phenols in a watercourse are toxic and can cause extensive fish kills even at concentrations in the 0.1 ppm range. At lower concentrations it is toxic to lower biological forms which were eliminated destroy the delicate balance of an aquatic environment.

Phenols at high concentrations can act as a shock load and can be toxic to bacteria used in activated sludge treatment plants. After being properly acclima-

tized, a secondary sewage treatment plant can be used to treat phenolic discharges however the feed rate to the plant should be maintained at near constant levels to eliminate shock load and withdrawl effects. Biological treatment systems have been set up to treat industrial wastes containing high phenol concentration with a high degree of success.

Cyanide

Cyanide can be introduced to the waste in various forms all of which can liberate the toxic hydrogen cyanide gas having a characteristic almond smell when the pH of the effluent drops to less than 8. Cyanides are used extensively in plating industries and hence this material is normally associated with other metals such as copper, zinc, and cadmium. Cyanides may also be discharged from gas works, coke ovens, and chemical industries.

Cyanides are extremely toxic to fish and have been responsible for numerous fish kills throughout the province. Cyanide also increases the toxicity of metals and hence can render normal background levels lethal to aquatic life.

The discharge of a strong cyanide waste to a sanitary sewer is first a potential health hazard. Cyanide

gas can be liberated from the waste and can become trapped in poorly vented manholes and other dead areas in the sewers representing a real hazard to maintenance workers. Cyanide is extremely toxic to bacteria and hence can create operational problems at the sewage treatment plant. Enough cyanide in the waste can kill off the bacteria in the secondary stage necessitating a new start up of operation. If smaller amounts of cyanide are received at the plant at constant levels the bacteria may become acclimatized and treat this waste quite effectively.

<u>Oils and Greases</u>

Greases and oils in wastes are commonly denoted by the term ether solubles or hexane solubles. The term does not differentiate between materials of animal or mineral origin. Since oils and greases act very similarly they can be readily discussed under and denoted by the one term. Oils and greases having an animal or vegetable origin are somewhat less noxious since they are more biodegradable.

Large quantities of oil discharged to a watercourse can have extensive damaging effects. Beaches covered with oil become unsightly and cannot be used for recreational purposes. Water fowl, weeds, and other

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vegetation covered with oil cannot continue with their normal life functions and die. Small quantities of oil can spread and cover large surface areas of water and prevent the proper penetration of light so necessary for proper weed growth. In domestic water supplies oils can import unpleasant taste and odours rendering the water unfit for human consumption. Treatment is therefore necessary to prevent the discharge of these materials to a watercourse.

Large quantities of grease and oil can create problems for a sewage plant operator. Grease can combine with other solids and produce large round solid masses more commonly known as "grease balls". A sufficient number of these can plug sewers and lines creating a number of maintenance problems. Smaller grease balls floating on the surface of clarifiers and aerators can create an unsightly mess. Their removal becomes an extra procedure that the operator must go through to have a properly operating plant.

Oils can also form unsightly scums on surfaces of clarifier and aerators. Oil can cover equipment, plug air nozzles of diffusers and create other maintenance problems. In sewage treatment lagoons oil can cover

the surface of the pond interferring with the oxygen transferring mechanism. Extensive quantities of oil can also become a fire hazard especially if the oil contains gasoline that can evaporate and form an explosive mixture with air. Steps should therefore be taken at the source to prevent excessive oil discharges to the sanitary sewer.

MISCELLANEOUS

Nutrients

The term nutrient normally refers to nitrogen and phosphorus compounds in the waste that promote the growth weeds and algae. An overabundant growth of weeds and algae create nuisance problems in recreational areas. Masses of algae rotting on shore create odour problems, destroy the value of waterfront property and make the area uninhabitable. Treatment systems have now been designed to remove these materials from the waste.

Colour and Turbidity

Colour and turbidity are useful parameters when determining the nuisance values of some wastes. Strongly coloured effluent say from a dyeing industry may impart an objectionable colour to a lake or river destroying its aesthetic value. Highly turbid

streams may also look objectionable and can prevent a proper passage of light necessary for good aquatic growth. In some cases dyes can be broken down quite readily in a sewage treatment plant. In most cases however, the more modern dyes are extremely stable and can only be handled by straight dilutions.

Toxicity

In some cases it is difficult to assess the nature of a particular waste and predict its harmful effects on aquatic life. To determine whether such a waste can be released to a watercourse a toxicity test may be carried out. This test involves immersing minnows into various dilutions of the waste and studying the effects of this waste on the fish. If the fish survive, the effluent is taken to be non toxic, if the fish die, the dilution is noted and this can be used to set effluent quality standard. With more and more new chemicals being created, the toxicity test has become a handy tool to evaluate some of the more exotic type wastes.

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GENERAL METHODS OF TREATMENT
OF INDUSTRIAL WASTES

In the previous presentation, many of the common components and parameters associated with industrial waste discharges were discussed. The need to reduce the quantities of these contaminants or remove them altogether from the wastewaters was highlighted on the basis of the harm that could befall the municipal sewerage system or the natural watercourse receiving such untreated wastes. The purpose of this presentation is to make you aware of some of the more common methods of treatment available to treat these wastes. The presentation will be basically descriptive and non-technical. If further technical details or design data are required, the reader is referred to any one of a number of standard texts listed in the appendix.

With the variety of contaminants encountered in industrial effluents it is difficult to select a logical approach to a presentation on treatment methods without wondering if it will be the approach that will be most beneficial to the reader. After much deliberation, it was decided to present the treatment methods in a manner which will stimulate some thought on the part of the municipal inspector, engineer, etc., as to the types of waste contaminant he should be looking for and, at

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the same time, retain some logic to the presentation.

In looking at the problems of industrial waste effluents we are dealing with either physical mixtures or solutions of solid, liquid or gaseous components in water. The problem of waste treatment then resolves itself simply to one of how best to minimize the concentration of the offending component or eliminate it altogether from the water. With this in mind, three basis systems will be dealt with:

(1) Water-Solids Systems

(2) Water-Liquids Systems

(3) Water-Gaseous Systems

Most of the problems encountered in the industrial wastes field are with water-solids systems, but the municipal inspector, engineer, etc., should be aware at all times that the other types of system do exist and can create severe pollution problems.

(1) WATER-SOLIDS SYSTEMS

To facilitate a better understanding of the water-solids systems, it is convenient to break them down into systems involving two categories.

(a) Suspended Solids

(b) Dissolved Solids

Further, the dissolved solids systems could be broken down into two sub-categories, "dissolved organic solids" and "dissolved inorganic solids". Such a breakdown, however, could lead to some confusion as a number of the treatment systems to be discussed are applicable to both organic and inorganic solids. Therefore, "Dissolved Solids" will be dealt with on the basis of treatment systems and mention will be made if a particular system is applicable to the treatment of both dissolved organic and inorganic solids.

SUSPENDED SOLIDS

At one time or another, each of us has personally encountered a problem of removing suspended solids from water either to recover the solids or to recover the 'clear' water. The wine maker clears his wine by allowing the suspended solids (yeast cells, etc.) to settle over a long period and then decants the 'clear' supernatant wine into bottles. The housewife strains the cooked vegetables or rice through a colander, retaining the food and discarding the cooking water. The coffee maker filters the mixture of water and coffee grounds to retain the 'clear' coffee and discard the grounds. Each of these is an example of standard techniques that are applied universally to the problems of water-suspended solids

separation. They will now be examined a little more closely:

(1) Screening

Screening is the simplest method of separating suspended solids from liquids. Any device containing holes through which the liquid will pass but the solids will not is considered to be a screen. The colander is simply a functional screen for the housewife.

In practical industrial applications, a variety of shapes and sizes of screens are encountered and screening generally represents the cheapest method to effect a solids-liquid separation. Screens do suffer from one major drawback and this is the tendancy for the holes to become plugged by the solids resulting in a subsequent reduction in liquid throughput capacity. Most innovations in the design of screens have been aimed at preventing plugging and increasing liquid throughput. This has generally been accomplished by imparting some mechanical action to the screen so that it becomes self-cleaning. A more recent innovation, the DSM screen (Dutch State Mines) directs a jet of the liquid-solids suspension tangentially onto the surface of a vertical parabolic screen such that the solids are retained on the surface of the screen and fall downward under the

action of gravity while the water passes through the screen.

It follows naturally that the finer the screen (the smaller the holes) the more screen area is required for a given liquid throughput. This factor often places a practical limit on the size of solids particles that can be removed by screens. In general, it is true to say that the use of screens is restricted to the removal of larger size particles, seldom less than 150 microns (0.006 inches or 100 mesh).

Some of the more common types of screen are:

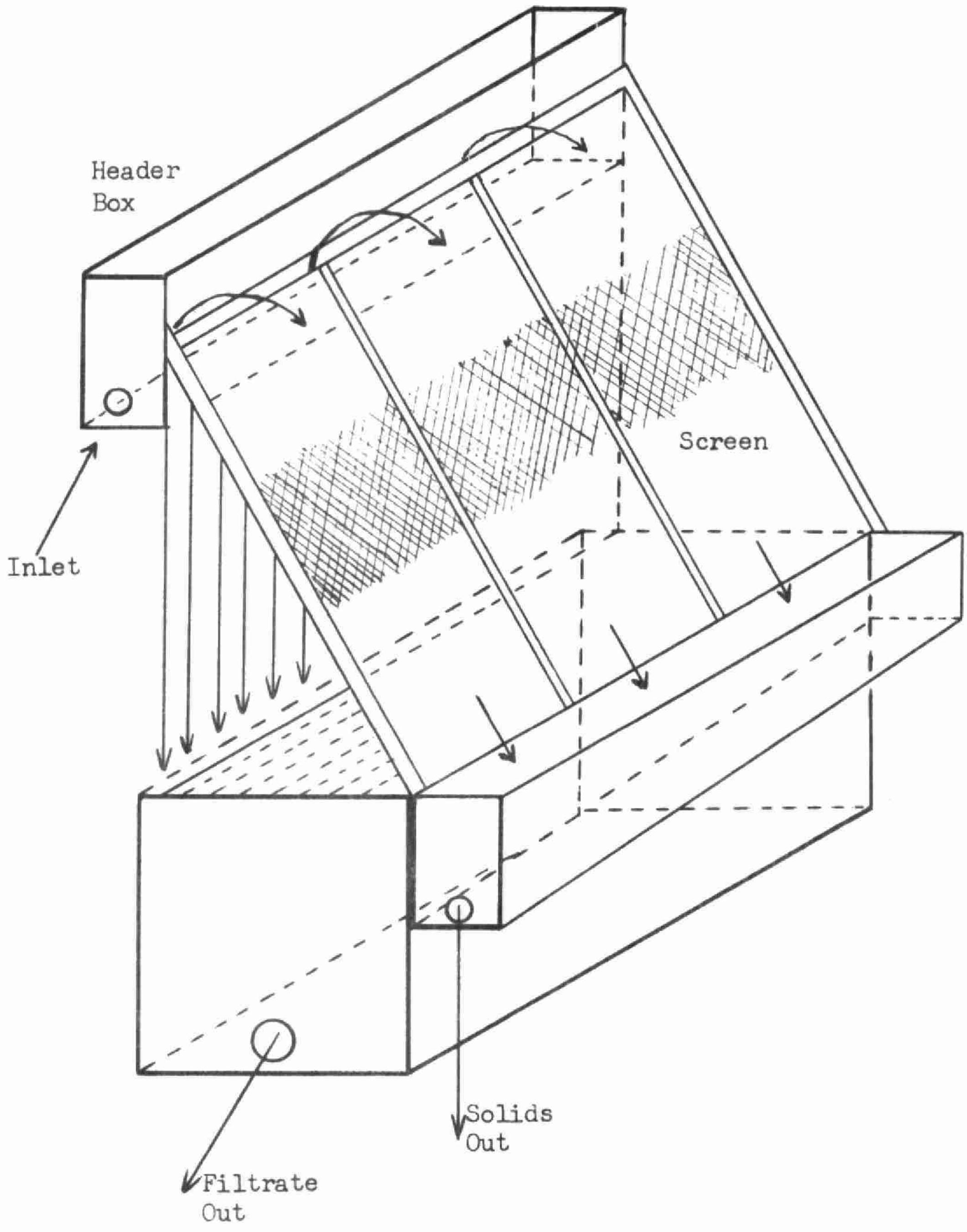
(a) Gravity Sidehill

Gravity Sidehill is simply a piece of wire mesh or a number of equally spaced metal bars, inclined to the vertical (see Fig I). The liquid solids mixture is poured onto the surface and the liquid passes through while the solids are retained by the screen to be collected at the bottom.

(b) Rotary Screen

In this type of screen, the wire mesh is formed either into a cylinder which is rotated or an endless belt. The liquid-solids mixture is either fed into the cylinder, allowing the water to pass through

FIGURE I



SIDEHILL SCREEN

the mesh and the solids to accumulate inside, or to the outside of the cylinder allowing the liquid to flow through the mesh to the inside of the cylinder and the solids to accumulate on the outside surface. Suitable devices are arranged to remove the accumulated solids.

(c) Vibrating Screens

May be rectangular or circular in shape, may be inclined, and may have more than one unit of mesh stacked one above the other. A vibrating motion is imparted to the screen which assists in keeping the screen from plugging and also imparts motion to the accumulated solids so that they 'flow' to a suitable discharge point.

(2) Sedimentation

Sedimentation utilizes the fact that suspended solids particles having densities greater than that of the water in which they are suspended, will move through the water under the influence of a suitably applied force. In most sedimentation systems the applied force is gravity and the movement of the solids through the water is termed settling. In the case of the centrifuge, the applied force is centrifugal force and the movement of the solids will be outward from the axis of rotation of the centrifuge.

The type of sedimentation device to be selected will depend, to some extent, on the amounts of settleable solids present in the mixture. If large quantities of solids are to be removed, it will be necessary to select a system in which the removed solids can be easily recovered for continuous disposal. If the quantity of solids is relatively small, a system wherein the accumulated solids are only recovered for disposal once or twice per year may be adequate. Also, it is possible to design systems wherein the solids are not recovered and the system then also becomes a disposal system - e.g., mining industry tailings areas.

Theoretically, any solid particle having a density greater than that of water will settle under quiescent conditions but in practice this is not the case. When particles become small, in the micron range, they exert a random movement effect known as 'Brownian Movement' and will not settle. Also, when particles are small they are more readily subject to the influence of small forces present all around. Therefore, it is not always possible to settle-out all of the suspended solids in a practical time frame. Bench and pilot studies will normally determine the fraction of the suspended solids that can be removed by settling. The following are

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examples of different sedimentation techniques:

(a) <u>Sedimentation or Settling Ponds</u>

Sedimentation ponds may range from suitably shaped holes dug in the ground to concrete basins. The purpose is to provide a quiescent environment in which the solid particles can settle and also to provide sufficient capacity for the settled solids to accumulate without interfering with the settling process.

A suitable device should be placed at the feed end of the pond to distribute the flow evenly across the width of the pond, thereby utilizing the full pond area. A similar device should also be placed at the discharge end. Theoretically, sedimentation is independant of depth but, from the practical standpoint, the ponds should be deep enough to prevent wave-action from stirring up the pond contents and to provide sufficient capacity to store accumulated solids. A depth of about 5 feet is the recommended minimum.

The major drawback to ponds of this type is the costs associated with the removal of accumulated solids. For a plant with continuous manufacturing operations, it will be necessary to install two ponds so that one

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can be in operation while the other is being dewatered and cleaned. Obviously, dewatering and cleaning during the winter time is probably not practical and cleaning schedules must therefore be carefully planned.

Where degradeable materials are settled-out, potential odour problems during warm weather can arise as the settled materials undergo anaerobic decomposition. One successful method of control against odours is to ensure that the pH of the pond contents is raised above 9. If this is done, it may be necessary to neutralize before the contents are discharged.

In sandy soil, it is sometimes possible to construct sedimentation ponds from which there is no visible discharge, the wastes flowing away by percolation through the sand into groundwater. From a treatment standpoint, this type of system has many advantages but test wells should be dug in the vicinity of such ponds to test for groundwater contamination. Fig II shows a typical sedimentation pond system.

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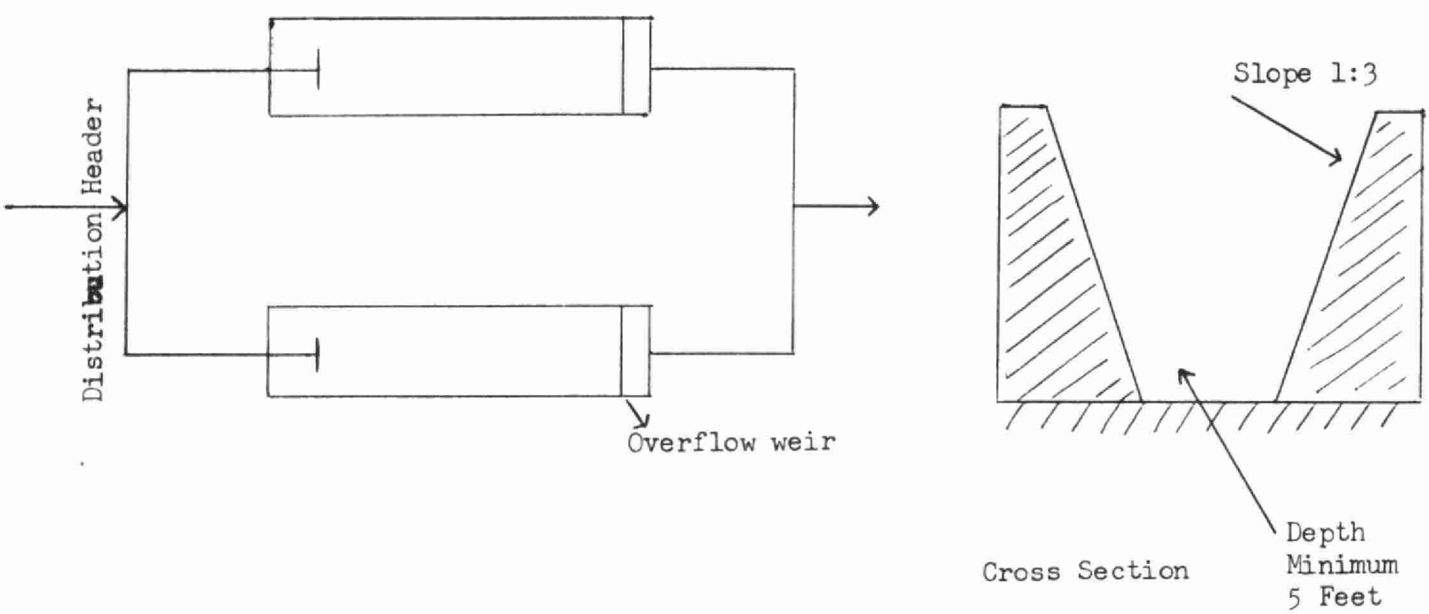
FIGURE II



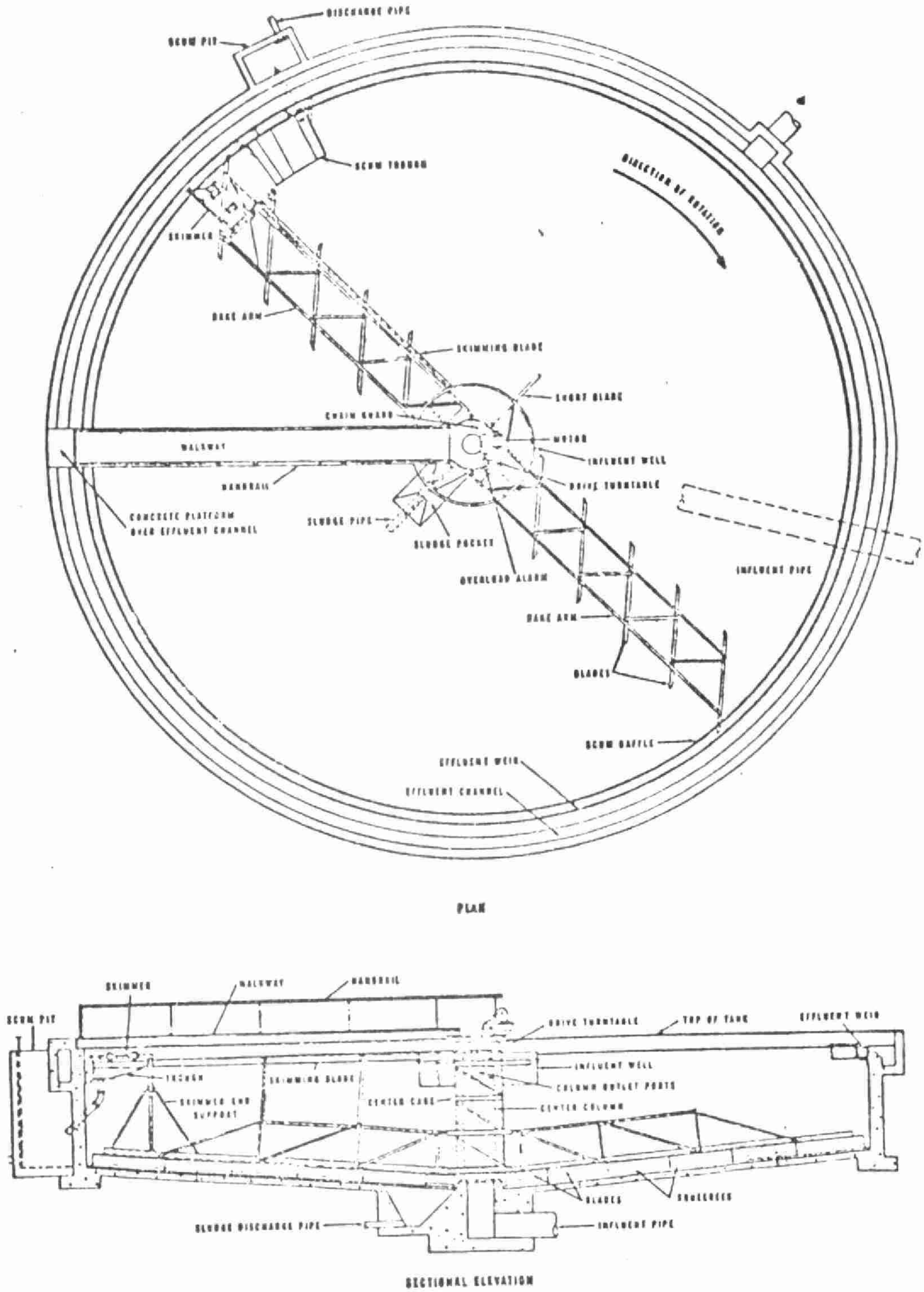
(b) <u>Clarifiers</u>

A clarifier is a suitably shaped vessel or earthen basin from which settled solids are continuously removed by mechanical means. Most clarifier basins are constructed of concrete or steel with the earthen basin normally reserved for large versions.

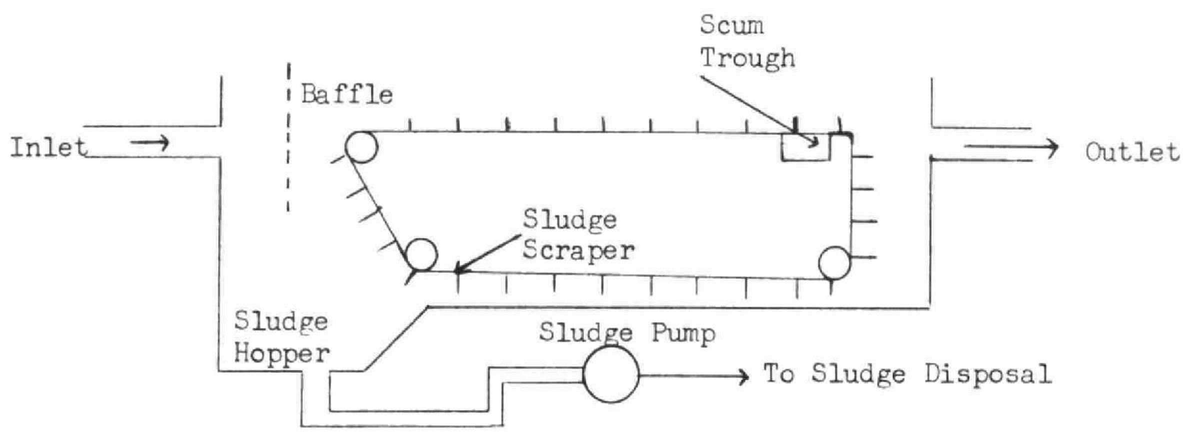
The mechanism for removing the settled solids or sludge normally consists of a rake to move the sludge to a convenient point and a pumping system to pump the sludge to a disposal system. In the circular clarifier the rake is pivoted at the centre and rotated by means of a central or peripheral drive. Sludge removal takes place from a central sludge well. Fig. III shows the arrangement of a circular clarifier.

FIGURE III

CIRCULAR CLARIFIER



In the rectangular clarifier, the rake is normally attached to an endless chain belt with the sludge being continuously moved to a sludge well at the feed end. Fig. IV shows a common type.



Circular clarifiers can be constructed to include a flocculating chamber in which fine, non-settling particles can be flocculated with the aid of chemicals. This type of clarifier is known as a "Reactor Clarifier". Also, gravity sludge thickening can be incorporated into the bottom of the circular clarifier. The purpose of this is to dewater the sludge as much as possible before removal from the clarifier. The nature of the solids being settled-out will determine whether thickening should be incorporated.

Sludge dewatering or thickening is vital, in most cases, to the satisfactory disposal of sludges and, as the term implies, its prime function is to remove water

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from the sludge, thereby conditioning the sludge to the point where it is 'thick' enough to be burned or hauled away for land disposal. Economics will dictate the degree of water removal required. If the sludge is to be burned, the cost of removing water must be balanced against the fuel consumption of the incinerator or the fuel value of the sludge material. If the sludge is to be hauled away for land disposal the cost of hauling 'water' must be balanced against the cost of removing water.

The most common methods used to dewater sludges are:

(1) gravity thickening

(2) vacuum filtration

(3) centrifuge

The operating principles of the vacuum filter and centrifuge will be discussed later but the merits of each in application to sludge dewatering will largely depend on the characteristics of the sludge being dewatered. Gravity thickening is accomplished in a vessel similar to a clarifier. This provides the additional settling time required for the sludge to thicken. Rate mechanisms are generally stronger to accommodate the greater torque associated with the 'thicker' sludges.

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(c) Centrifuges

Centrifuges are made in a variety of types and sizes for different applications but, in this presentation, only the sedimentation centrifuge will be considered. In the sedimentation centrifuge, solids are removed from liquids by causing the solid particles to "settle" through the liquid radially towards or away from the centre of rotation. If the solids are more dense than the liquid they move outward and deposit on the surface of the bowl from which they may be removed by a suitable mechanism. In some designs, the solids are not allowed to deposit on the walls but are removed continuously through ports as a thick slurry. Most sedimentation centrifuges are comparatively small in diameter and operate at extremely high speeds.

Most sedimentation centrifuges operate continuously with respect to feed and liquid discharges.

Fig. V shows a horizontal, concurrent flow centrifuge, typical of the types used to separate large amounts of solids from liquids.

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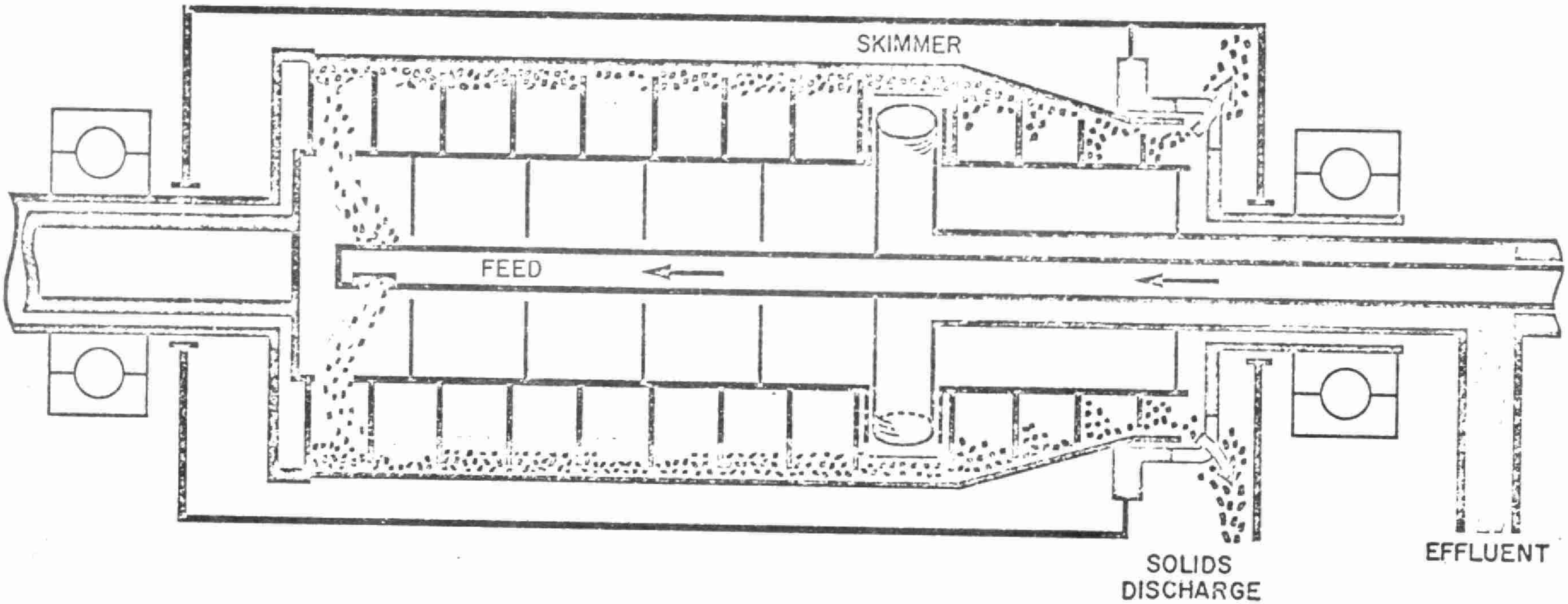
FIGURE V

CONCURRENT FLOW CENTRIFUGAL



Centrifuges, because of the high speed of operation, are subject to maintenance problems. In particular, the internal vanes are subject to erosion if sandy or gritty particles are present. These problems can be overcome by care in operation and selection of the correct materials of construction.

The removal of solids by the centrifuge is not a very efficient process as the recovery of solids from the liquid decreases rapidly as the solids content of the slurry increases. Thus the effluent or filtrate from the centrifuge is usually not suitable for discharge to a storm sewer or watercourse although it may be suitable for discharge to a municipal sewer. Flocculating chemicals can be added to the feed to the centrifuge to improve the solids recovery, but this adds a cost factor to the system. The main advantage of the centrifuge is that it is a compact piece of machinery capable of handling high throughputs and requiring very little floor area compared to a clarifier or settling pond.

(3) Filtration

Filtration may be defined as the separation of suspended solids materials from a liquid by passage of

most of the liquid through a membrane or medium that retains the solids on or within itself.

The clear liquid effluent resulting from the filtration process is called the 'filtrate' and the solids accumulated on the membrane are known as the 'filter cake'. Passage of the liquid through the membrane may be accomplished by gravity, by pressure or by vacuum, which leads to one method of differentiating between filters. Other differences will depend on whether the filter is batch or continuous in operation and whether the prime function is to recover the solids or produce a 'clear' filtrate.

With most types of suspended solids, as the filter cake builds up and increases its thickness, the resistance to the passage of the liquid increases to the point where the rate of flow of liquid becomes so small as to be of little practical value. To overcome this problem, it is necessary to 'renew' the filter surface and this can be accomplished by the use of rotary type filters, endless belt type filters or by stopping the filtration process and washing-off the accumulated cake. In a continuous operation, the cake is continuously removed and the filter membrane or medium is washed to present a new surface. In a batch operation it is necessary

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either to dismantle the filter and wash-off the accumulated cake or to backwash the filter using high pressure water. Filter backwashing can be automated either on a time cycle or pressure cycle and a number of batch filters can be used on a staggered basis with a common feed to provide continuous filtration.

The filter membrane or medium can be made of a variety of materials. Most commonly, filter media are made of cloths, the composition of the cloth being selected for its resistance to chemical attach and its permeability. Wire cloths with very fine mesh are also used. Where very fine particles are to be removed from suspension, a cloth alone is frequently unable to do this and it becomes necessary to build up a layer of some suitable porous material on the cloth to do the actual filtering. This process is known as "precoating". The filter medium may also consist of a bed of porous material, such as sand, contained in a suitable vessel. This type of filter is frequently used in water treatment applications. Some comments on pressure and vacuum filters follow:

(a) Pressure Filters

A pressure filter may be described as any filter in which the material to be filtered is fed to the filter

under pressure, normally provided by a pump or compressed gas. Pressures in the range of 50 - 75 lb/sq.in are common and pressures as high as 500 lb/sq.in are in use.

Most pressure filters are batch or intermittently operated mainly due to the difficulty of removing the cake from a pressurized environment. Some of the advantages claimed for pressure filters are:

- relatively rapid filtration occurs under high pressure and allows difficult separations to be made in practical time limits.
- due to their compactness, a large filtration area per unit of floor space is provided.
- they are flexible and have a relatively low initial cost.

The main disadvantage to this type of filter is the high operating costs, usually associated with the high labour requirements.

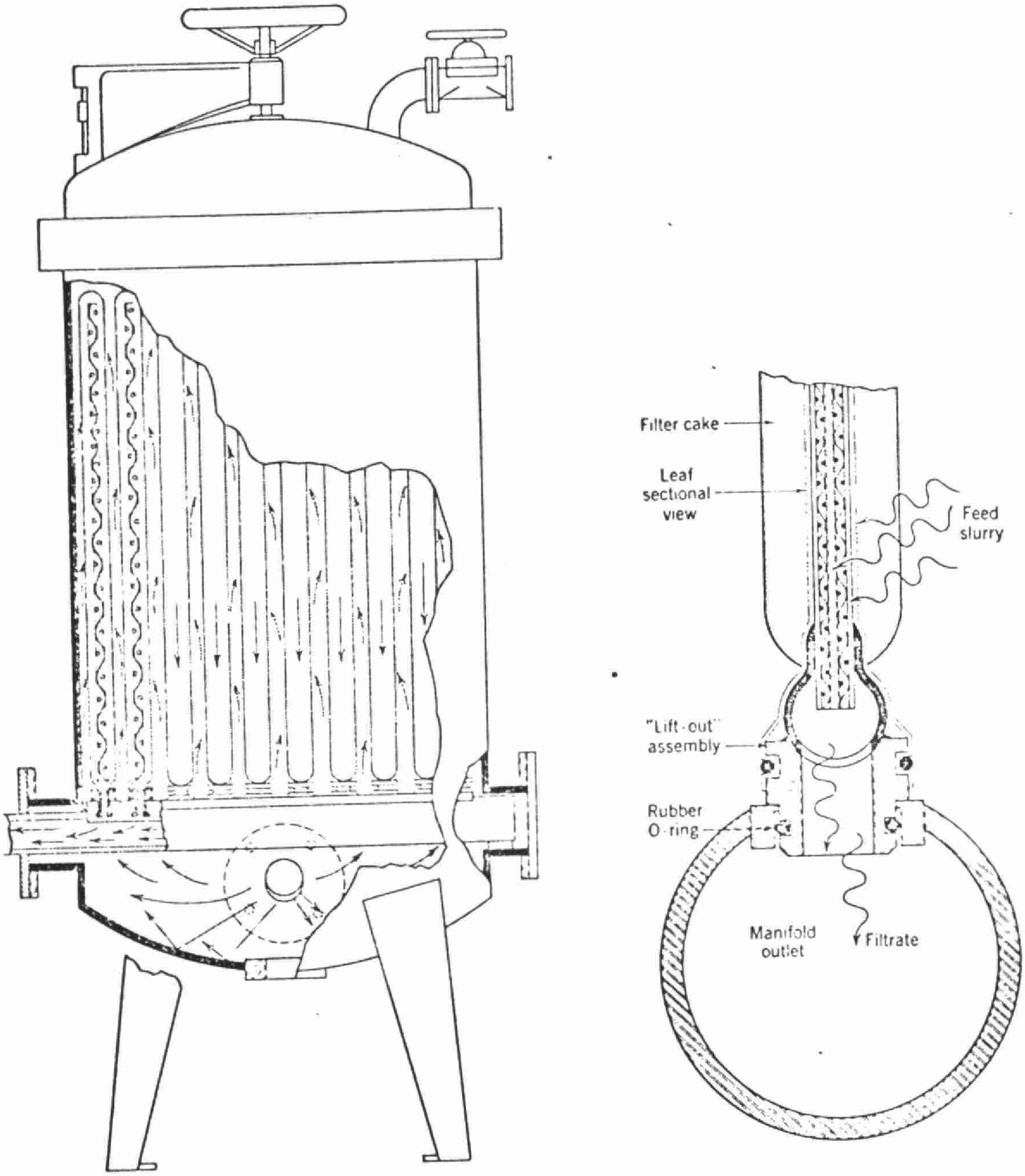
Fig. VI shows a pressure leaf filter.

(b) Vacuum Filters

Vacuum filters are those which operate with less than

FIGURE VI

PRESSURE LEAF FILTER



atmospheric pressure on the downstream side of the filter medium. In effect, the liquid is sucked through the filter medium by the vacuum. As the upstream pressure is normally atmospheric, the vacuum filter is limited to a maximum filtering pressure of approximately 1 atmosphere or 14.7 lb/sq. inch.

The filtrate from a vacuum filter will be at the pressure of the vacuum and will need to be "compressed" before it can be discharged from the filter. This is accomplished either by a barometric leg or a filtrate pump. The vacuum may be supplied by a mechanical vacuum pump, an ejector system or by providing a seal on the barometric leg.

The advantages and disadvantages of vacuum filters are listed below:

Advantages

- they can be designed as effective continuous filters and, as such, can be employed readily in continuous processes
- they have low labour requirements
- the filtering surface can be open to the atmosphere and therefore is easily accessible for inspection and maintenance, even during operation.

- maintenance costs are relatively low.

Disadvantages

- a vacuum system must be provided and maintained.
- the filters cannot be used with filtrates that are volatile, whether because of low boiling point or high operating temperatures.
- they are inflexible and do not perform well if the feed stream changes with respect to rate, consistency or character of solids.

Two types of vacuum filter are in common use. These are the rotary filter and the disc filter. In the rotary filter, the filter medium covers the surface of a cylindrical drum which rotates on a horizontal axis and which is immersed in a bath of the liquid to be filtered. The inside of the drum is compartmentalized into segments to which a vacuum may be applied and then released as the drum revolves. The filtrate passes to the inside of the drum and is removed by some suitable device. The solids are released from the filter medium either by blowing-off with air, by scraping off with a doctor knife, or merely by allowing them to fall off as the filter medium passes over and under a set of rollers. The disc filter works on a similar principle

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except that the filter is made up of a number of discs attached to a common rotating horizontal shaft such that the discs rotate in a vertical plane. Both sides of the discs are covered with filter medium and the inside of each disc is segmented as in the case of the rotary filter. Removal of accumulated cake is normally accomplished by blowing with air.

Fig. VII shows schematically the arrangement of rotary drum and disc filters.

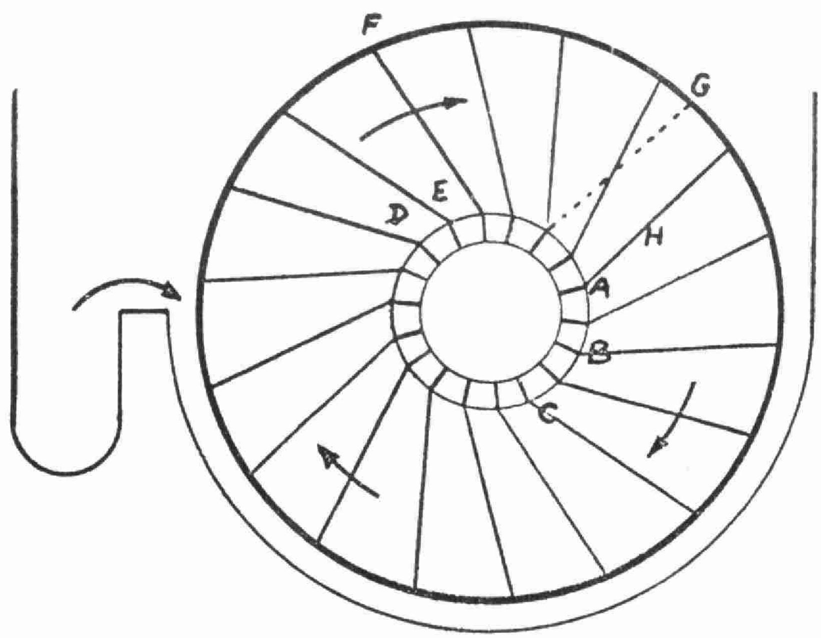
As mentioned earlier, filters are made in a variety of types and sizes, and only a few of these have been mentioned here. The selection of a filter for a specific suspended solids removal problem will depend on many factors with the two most important ones being the clarity of filtrate required and the relative cost of achieving this clarity.

(4) Flotation

Separation of suspended solids from a liquid by flotation is effected by introducing very fine bubbles of air into the solid-liquid mixture at a point below the surface. The air bubbles rise and are either trapped by the particle or adhere to it, thereby increasing the

FIGURE VII

ARRANGEMENT OF ROTARY DRUM AND DISC FILTERS



FILTER OPERATION

A. Sector begins to fill by gravity from core outwards.

B. Vacuum on; cloudy filtrate collected.

C. Clear filtrate obtained.

D. Vacuum off.

E. Atmosphere port opens.

F. Take-off mechanism peels off mat.

G. Wire washing begins.

H. Atmosphere port closes.

buoyancy of the particle to the point where it will 'float' to the surface. The accumulated particles can then be removed from the surface by some suitable means. Improved flotation is achieved by the use of a variety of chemical additives which serve to coagulate the solid particles to promote more stable bubbles and to lower the surface tension between the solids and the liquid.

Flotation is widely used as a separating process for minerals in the mining industry but employs a system that is different to the Dissolved Air Flotation system which has application in the waste treatment field. As the name implies, dissolved air flotation operates on the principle of dissolving air into water under pressure so that when the pressure is released, minute bubbles of air are formed in the water which carry solids in suspension with them as they 'float' to the top. The advantage of this type of system is that the air bubbles are much smaller than any that could be produced by mechanical means.

Fig. IX shows a typical dissolved air flotation system.

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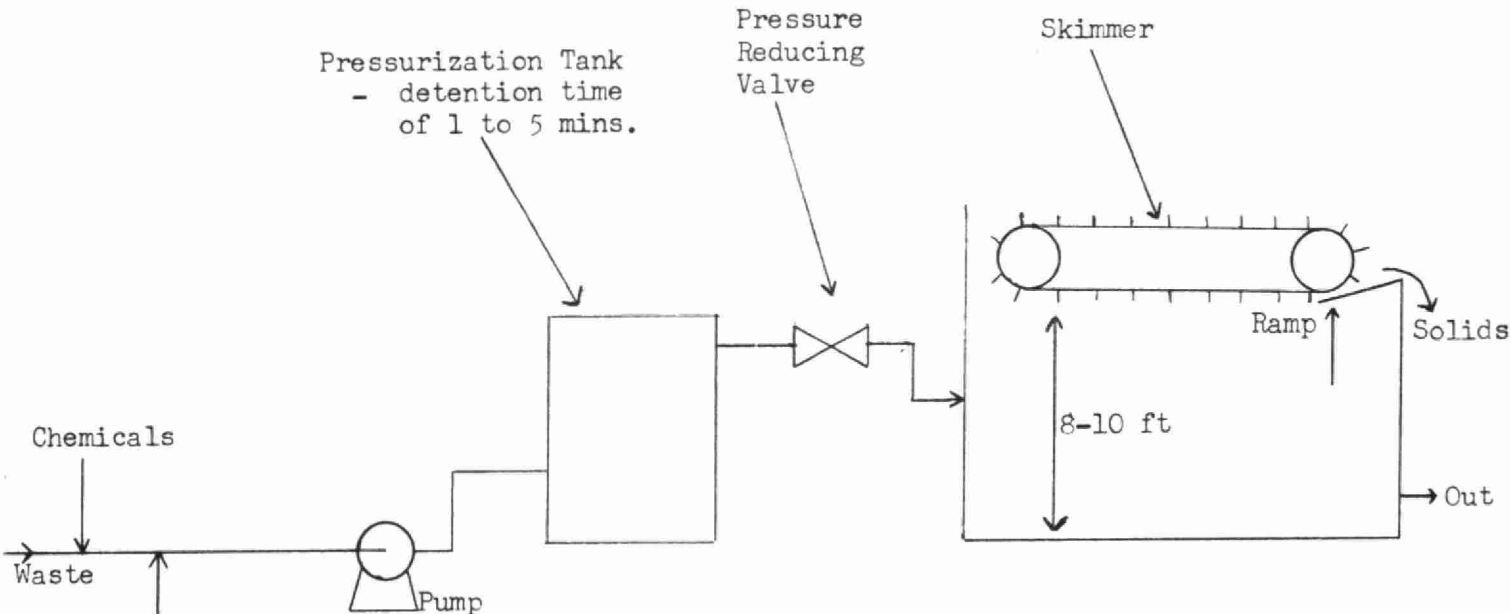
FIGURE IX

DISSOLVED AIR FLOTATION SYSTEM



To conserve chemicals, it is possible to recycle a portion of the effluent from the flotation tank and pressurize only it with air. This has the added advantage of minimizing the risk of breaking-up flocculent particles that may be in the waste feed as these do not then have to pass through the aeration pump.

Flotation units are not very flexible, requiring fairly uniform feed rates and characteristics. Their ability to handle surges of suspended solids is limited.

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DISSOLVED SOLIDS

From earlier discussions it should be obvious that industrial wastes can be extremely complex, requiring a variety of treatment processes to reduce or remove offending contaminants, particularly where these contaminants are in the form of dissolved solids. Traditionally, two types of treatment have been used; biological treatment and chemical treatment. Today, with the development of more sophisticated technology and better economics, a number of alternative treatment systems are available to complement or displace the more traditional methods. However, biological treatment and chemical treatment continue to be the mainstay of industrial waste treatment and emphasis will be placed on these two.

CHEMICAL TREATMENT

It is probably true to say that with the abundance of chemicals available to man today, a treatment system using chemical treatment as a basis could probably be developed to handle every dissolved solids waste problem. However, most of these systems would be economically very unattractive and, therefore, the types of chemical waste treatment in general use are limited to a few well established processes.

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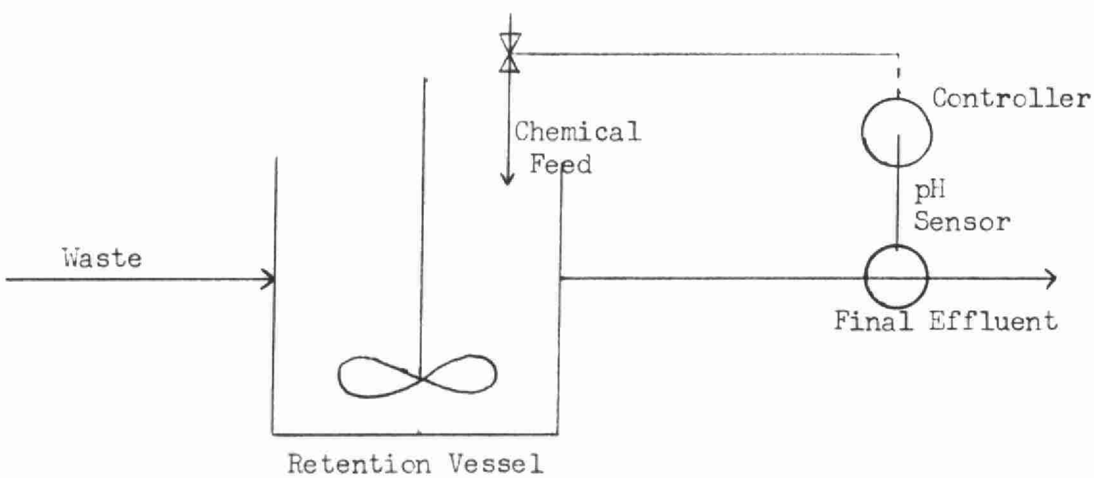
Included with chemical treatment, although probably deserving of a category of its own, is "neutralization and pH control". With most treatment systems, neutralization and pH control is a prerequisite and, in municipalities, it is desirable to maintain the pH of wastes being discharged to sewers to within a range specified by the by-law in order that adequate protection is afforded to the municipal sewers.

(1) <u>Neutralization and pH Control</u>

The process of neutralization involves the raising or lowering of the pH of a waste stream to the neutral point which occurs at pH7. On the other hand, pH control is concerned with maintaining the pH at any desired value within the range 0 - 14.

Fig. X shows a typical neutralization or pH control system.



A pH sensor measures the pH of the final effluent and controls the rate of feed of chemicals to a well mixed retention vessel. The purpose of the retention vessel is to provide adequate mixing of chemical with waste. The vessel may be omitted if adequate mixing of chemical and waste can be ensured by other means such as turbulent flow in a long length of pipe.

In practice, pH control systems tend to be unsatisfactory unless they are extremely well maintained and checked at frequent intervals. The pH probe itself tends to become readily fouled with deposits of materials and requires very frequent cleaning if good control is to be provided.

A variety of chemicals can be used to provide the desired acid, alkaline or neutral state. These chemicals can be fed in the solid, liquid, or gaseous form, with the liquid and gaseous forms generally providing a more satisfactory system. The feeding of solid materials at prescribed rates tends to be difficult to accomplish continuously in practice. Some of the more common chemicals used in the control of pH are listed below:

(1) Solids:

- slaked lime (calcium hydroxide)

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- calcium carbonate
- soda ash (sodium carbonate)
- alum
- magnesium oxide

(2) Liquids:

- slaked lime slurry (calcium hydroxide)
- caustic soda solution (sodium hydroxide)
- ammonium hydroxide
- liquid ammonia
- sulphuric acid
- hydrochloric acid
- nitric acid
- liquid sulphur dioxide
- liquid chlorine

(3) Gases:

- chlorine
- sulphur dioxide
- ammonia

The choice of chemical to be used will depend on the nature of the wastes, the size of the system and the economics.

(2) Precipitation

If the solubility of a chemical compound in water is very low, this can frequently be used to advantage as a method of removing certain materials from solution.

For example, many of the oxides of hydroxides of metal are relatively insoluble under specific pH conditions. By the addition of alkaline materials, these insoluble oxides are formed and can be removed from the water by sedimentation or filtration.

The phosphate removal systems presently being installed in many municipal sewage treatment plants are working examples of the use of precipitation to remove an undesirable material, in this case phosphate. By the addition of lime (calcium hydroxide) alum or ferric chloride, phosphate can be precipitated out as calcium phosphate, aluminum phosphate or ferric phosphate. (Actually, the compounds formed are not simple phosphates but this serves to illustrate the principles of the process.)

Examples of waste substances that can be precipitated from solution by the formation of an insoluble compound and then removed by sedimentation or filtration are given in Table A.

It must be stressed that conditions under which the precipitates are formed as readily settleable or filterable materials are often very critical, particularly with respect to pH.

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TABLE A
Removal of Soluble Substances By Precipitation

Substance	Precipitating Agent	Precipitate Formed
Nickel	Sodium or Calcium Hydroxide	Nickel hydroxide
Chromium	"	Chromium hydroxide
Copper	"	Copper hydroxide
Iron	"	Iron hydroxide
Mercury	Sodium sulphide or hydrogen sulphide	Mercury sulphide
Lead	"	Lead sulphide
Radium	Barium chloride/ sulphate	Radium Barium/ sulphate
Phosphate	Calcium hydroxide	Calcium phosphate
Sulphide	Lead nitrate	Lead sulphide
Chromate	Barium carbonate	Barium chromate
Bicarbonate	Calcium hydroxide	Calcium carbonate

The most common applications of precipitation occur in the plating industry, although removal of mercury by precipitation as mercuric sulphide is now the accepted method of treating effluents from the chlor-alkali industry.

(3) Cyanide Destruction by Alkaline Chlorination

Cyanides are used widely in the metal processing industries for metal plating, case hardening of steel and the refining of gold and silver.

Cyanides are extremely toxic, particularly under acidic conditions where they will form hydrogen cyanide.

In the alkaline chlorination treatment process, cyanides are oxidized by the addition of chlorine in the presence of sodium hydroxide to form sodium cyanate:

$$NaCN + Cl_2 + 2NaOH \longrightarrow NaCNO + 2NaCl + H_2O$$

The cyanate produced is only one one-thousandth as toxic as cyanide and will break down to yield ammonia and carbon dioxide. Further addition of chlorine and caustic soda will oxidize the cyanate to carbon dioxide and nitrogen:

$$2NaCNO + 4NaOH + 3Cl_2 \longrightarrow 2CO_2 + 6NaCl + N_2 + 2H_2O$$

Reactions are complete in about 10 minutes at pH 8.5.

The process can be conducted either in batch or continuous treatment systems. Fig. XI shows an Instrumented Batch Cyanide - Treatment System.

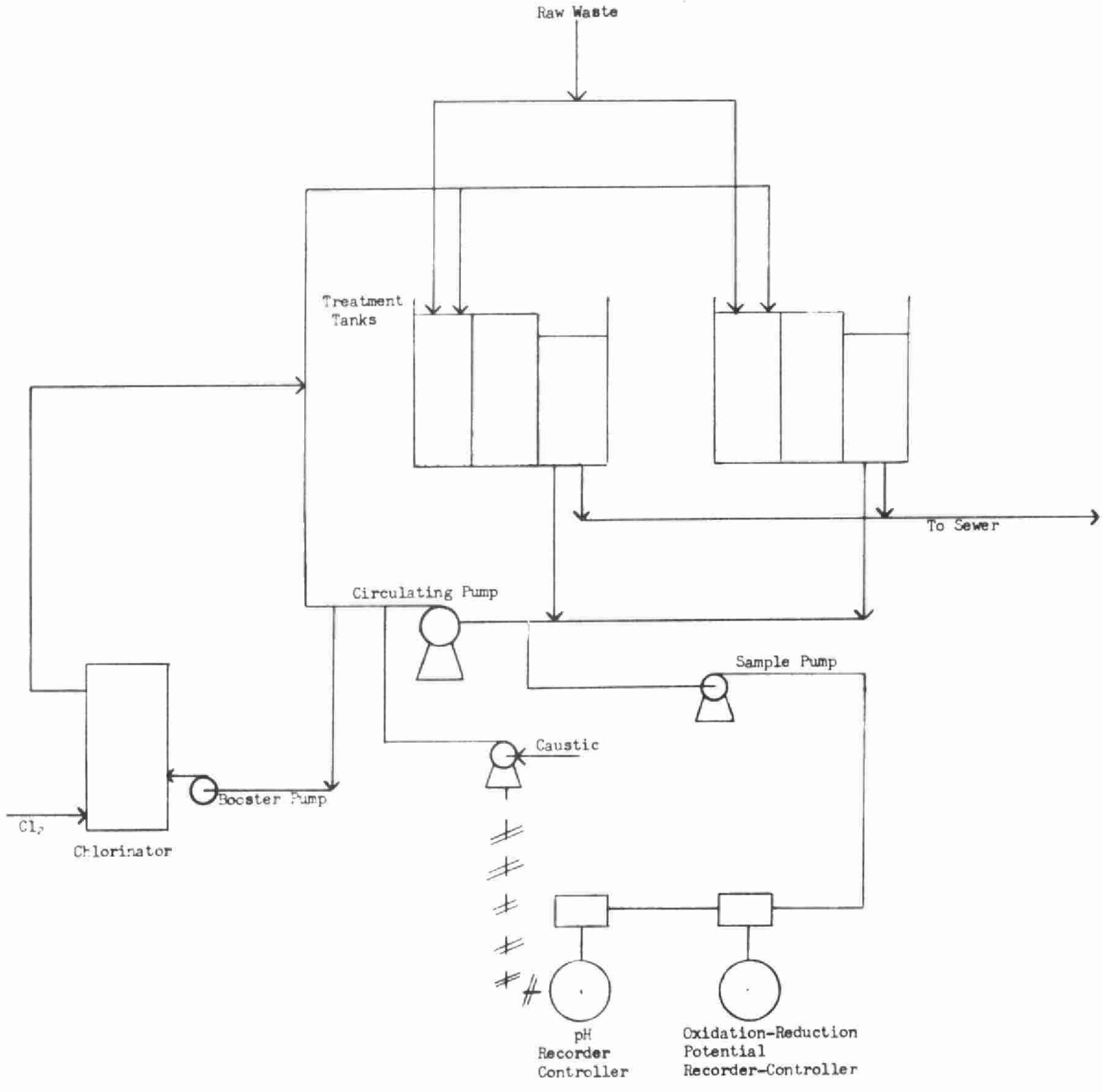
BIOLOGICAL TREATMENT

As mentioned earlier, biological treatment systems have been used in the treatment of domestic sewage since the early 1900's. In recent years, this type of treatment has found increasing use in the treatment of industrial wastes and is now an accepted part of industrial waste control.

The lower forms of life or "microbiota", such as bacteria and fungi, require much the same basic materials as human beings in order to grow and flourish. In particular, readily available sources of carbon, nitrogen and phosphorus are required which we obtain from the goods we eat. Bacteria, on the other hand, must obtain these vital elements from the waters in which they live and this means these elements must be present in the waters in a dissolved state so that the bacteria can "ingest" them through the cell walls.

FIGURE XI

INSTRUMENTED BATCH CYANIDE-TREATMENT SYSTEM



One ready source of carbon is the waste materials that we throw away from many of our manufacturing and processing operations. In fact, anything which we arbitrarily call 'organic' can be utilized as a source of carbon by some bacteria eventually. Thus, all 'organic' substances can be broken down by the action of bacteria and fungi. In order for these organisms to utilize the 'organic' materials as good, certain conditions must prevail in the local environment. Firstly, nitrogen and phosphorus must be present and available, and necessary trace elements, mostly metals, must be available. Secondly, certain basic elements such as oxygen, sulphur or iron must be present, depending on the types of bacteria, if the bacteria are to utilize the food source.

Bacteria, fungi, yeasts, algae etc., generally fall into one of two categories:

(a) those requiring elemental oxygen in order to carry out their metabolic processes.
 - "aerobic" organisms.

(b) those that can carry out their metabolic processes without the presence of elemental oxygen but which require compounds containing

oxygen such as sulphate, nitrate or
carbon dioxide to be present.
- "anaerobic" organisms.

There are some organisms that are able to adapt themselves to both situations. These are basically 'aerobic' organisms but they have the ability to grow anaerobically when the need arises and are known as "facultative" organisms.

With these two basic types of bacteria it is possible to develop two basic types of biological treatment:-

(a) Aerobic treatment in which oxygen has to be supplied.
(b) Anaerobic treatment in which oxygen is not required or in which it is excluded.

There is, of course, a third type of treatment which utilizes both types of bacteria and this is generally classified as facultative.

One of the secondary problems arising out of biological treatment is the production of solids or cell mass. Very roughly, for each unit of BOD removed by bacterial action, about 40 - 50 percent by weight is

converted into new cell mass (new bacteria) and the remainder is oxidized to carbon dioxide and water. It is the oxidation process that provides the energy necessary for the bacterial cells to carry on their functions of living and also to reproduce and create new cell material.

If the food supply to the bacteria is stopped, the cells will undergo auto-oxidation in which approximately 60 percent of the newly created cell mass will be oxidized to provide the energy requirements for the remaining cells. Thus, the minimum amount of new cell mass that will be created in a biological oxidation system is about 20 percent of the feed BOD. However, bear in mind that to accomplish this, it is necessary to limit the food supply and cause the bacteria to go into a state known as endogenous respiration.

If removal of these 20 percent solids is required, it must be accomplished by anaerobic decomposition.

(a) Aerobic Biological Treatment Systems

It is not the intention of this presentation to provide great detail of the various types of aerobic systems available. However, it is important that you be able to distinguish the differences in design and

application of the various systems.

The selection of a particular system will depend on many factors including, the ease with which the waste can be degraded and its characteristics, the volume of waste to be treated, the availability of land, the degree of treatment required, fluctuations in waste volumes and loadings, and cost.

The following list indicates the common aerobic biological treatment systems:

(i) Stabilization lagoon or pond
(ii) Aerated facultative lagoon
(iii) Activated sludge and extended aeration - oxidation ditch
(iv) Contact stabilization
(v) Trickling filter

(i) Stabilization Lagoon

Stabilization lagoons are very common for the treatment of domestic sewage where land is available. Two types of lagoon may be encountered. Firstly, there is the total retention lagoon from which there is no discharge for most of the year, with the lagoon contents being discharged only during periods of high stream

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flow in the receiving stream (Spring). Secondly, the lagoon may be designed as a flow through system.

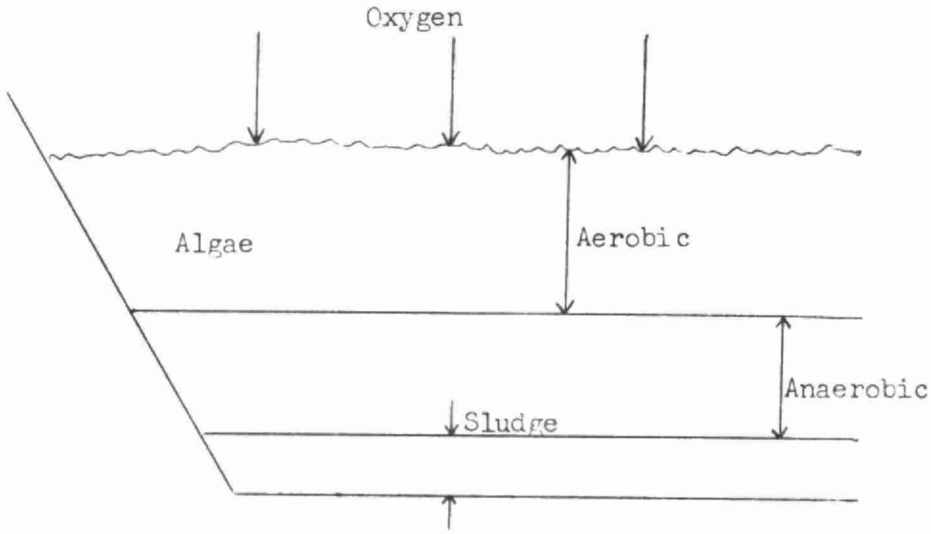
Lagoons are normally constructed to operate with liquid depths of 3 - 6 feet and designed on a basis of 20 pounds of BOD_5 per acre of surface area per day. Because of the relatively large land requirement, stabilization lagoons are limited to industrial applications having low daily volumes or to seasonal applications such as the Canning Industry.

Oxygen requirements for the bacterial oxidation processes are supplied by oxygen transfer from the air through the water surface, or by the activity of algae in sunlight, or a combination of both. Often an anaerobic layer develops on the bottom of the pond and the pond then becomes facultative. Solids which are produced by the bacterial oxidation will settle to the bottom and undergo anaerobic decomposition producing methane, hydrogen sulphide and other gases. Odour will be produced if the aerobic layer is not maintained.

Fig. XII shows a cross section of a facultative Stabilization basin.

FIGURE XII

FACULTATIVE STABILIZATION BASIN



(ii) <u>Aerated Facultative Lagoon</u>

This type of system is similar to the facultative stabilization basin except that oxygen is supplied to the lagoon by some suitable means such as diffusers or mechanical surface aerators. Because oxygen requirements can be satisfied much more readily and considerable mixing takes place, these systems can handle greater loadings of applied BOD. They are, therefore, relatively smaller in surface area and can be operated at depths of 10 - 15 feet. Care must be taken to ensure that the mixing is not too violent to prevent deposition of solids

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or the formation of the anaerobic layer.

Satisfactory treatment is usually obtained if the applied BOD_5 to the lagoon is limited to a maximum of about 3 pounds per 1,000 cubic feet of lagoon volume (3 lb. BOD_5/1,000 ft^3). The lagoon has the ability to handle substantial shock loadings without any severe reduction in the quality of the treated effluent.

(iii) <u>Activated Sludge Process</u>

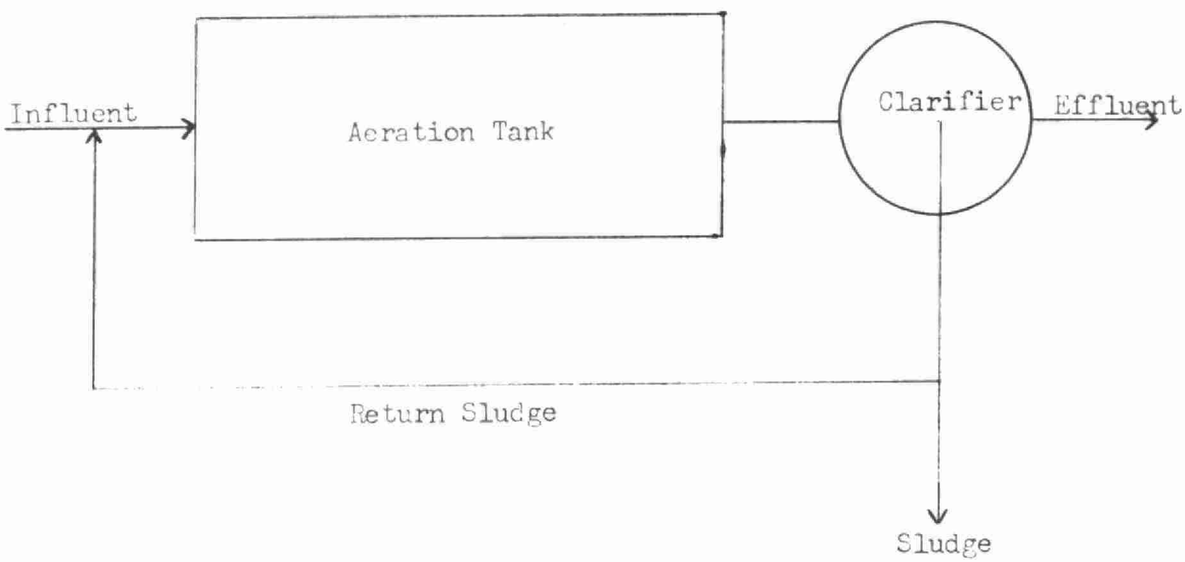
In this process, the oxygen requirements of the bacteria are supplied by mechanical aeration in an aeration basin. Solids or cell mass produced are then removed subsequently in a clarifier, known as a secondary clarifier. A portion of the solids is recycled to the aeration basin from the clarifier and the remainder is wasted and must be disposed of in a satisfactory manner.

Fig. XIII is a schematic of a conventional activated sludge process.

The process will work over a wide range of applied BOD_5 loadings but a limitation is impressed by the requirement to produce solids that will flocculate and

FIGURE XIII

CONVENTIONAL ACTIVATED SLUDGE PROCESS



readily settle. Also, the minimum recommended detention time in the aeration tank is one hour. A conventional system operates with an applied BOD_5 loading rate of 30 - 35 lbs. BOD_5 per 1,000 ft^3 of aeration tank but high-rate systems have been developed that operate with loadings in the range 400 - 500 lbs BOD_5/1,000 ft^3 of aeration tank.

A modification of the activated sludge system is the 'Extended Aeration System'. In this system, the bacteria are allowed to go into the endogenous respiration

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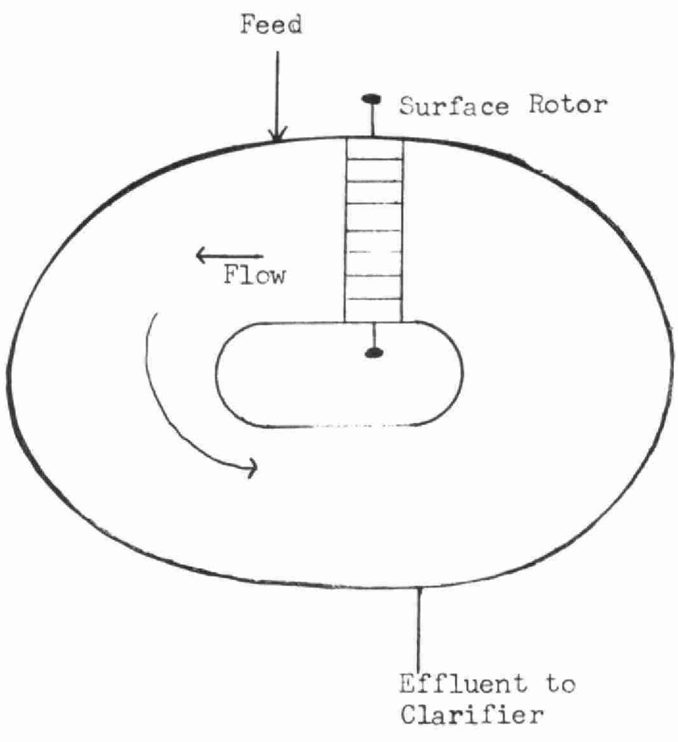
phase to minimize the production of solids and this is accomplished by providing additional aeration time.

The oxidation-ditch is an example of an extended aeration plant and is shown schematically in Fig. XIV.



Secondary clarification is still required but because the amounts of sludge generated are less, the sludge handling problems are lessened.

Table B indicates some typical design and operating parameters for activated sludge plants.

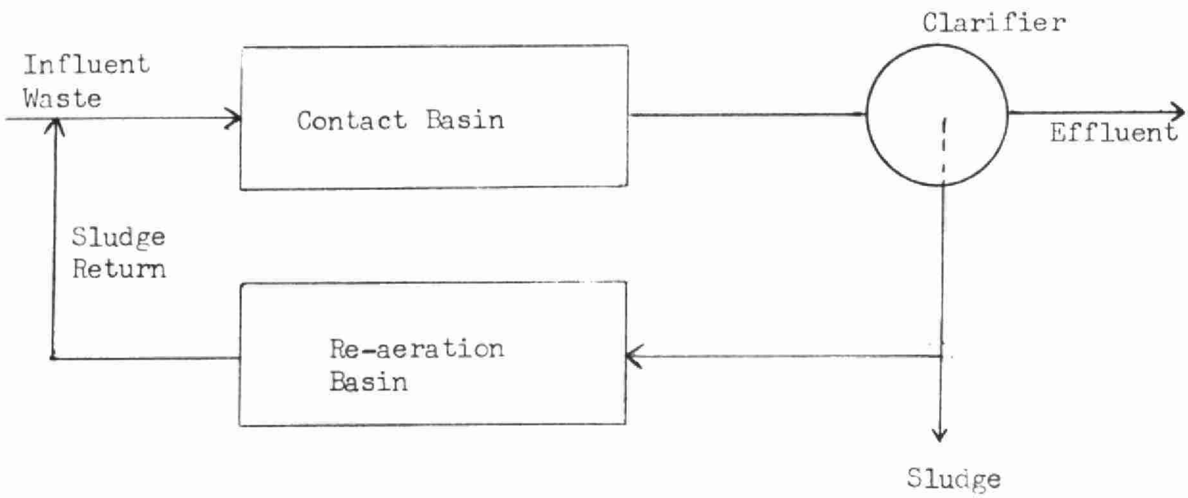
TABLE B

Activated Sludge Parameters

	Conventional	Extended Aeration
detention time in aeration tank - hrs	4 - 8	15 - 30
volumetric loading - lbs BOD_5 / $1{,}000\ ft^3$	30 - 35	12 - 25
BOD Removal efficiency	85 - 95	$>$ 95
Effluent quality - mg/l BOD_5	20 - 30 mg/l	$<$ 20 mg/l

(iv) <u>Contact Stabilization Process</u>

The contact stabilization process was developed to take advantage of the ability of activated sludge to absorb materials and is particularly useful when a large portion of the BOD_5 is in the suspended solids or colloidal form. Fig. XV is a basic schematic of the process.



The feed waste is mixed with activated sludge in an aerated contact basin having a retention time of 20 - 40 minutes. The activated sludge absorbs organics and is then separated from the liquid in the secondary clarifier. Some of the separated sludge is wasted but most is passed to a reaeration tank where the sludge is reaerated for a period of 1.5 to 5 hours. During reaeration, the organics absorbed by the sludge are utilized and the sludge is stabilized and reactivated. This process permits a reduction in overall aeration basin capacity.

(v) <u>Trickling Filters</u>

The trickling filter consists of a packed bed of suitable material down through which the wastes being treated are allowed to flow. Sufficient voids exist between the packing to allow air to pass upwards. A film of biological slime, similar in characteristics to activated sludge, grows on the surface of the packing, using the organics from the wastewaters as a source of food and energy. As the mass of slime grows on the surface, it reaches a point at which it can no longer adhere to the surface and then breaks away. Thus the slime growth is constantly renewed. Secondary clarification of the effluent is necessary to remove the biological solids.

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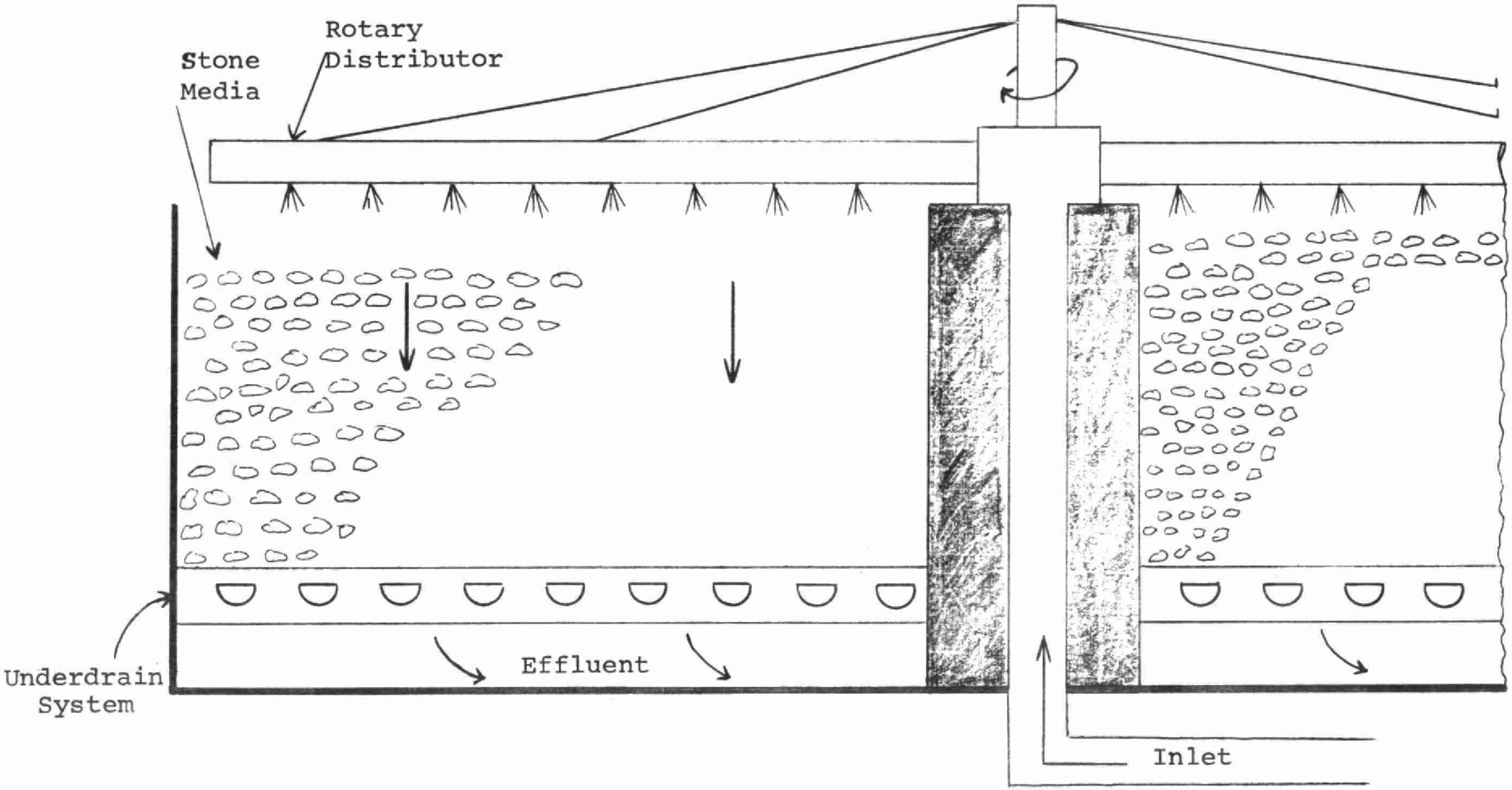
FIGURE XVI

TRICKLING FILTER



Trickling filters may be operated on a once-through basis, with recycle of effluent, and in series. BOD_5 removal efficiencies can range as high as 80 percent although generally, they will be somewhat lower. Trickling filters are generally less costly to build than conventional activated sludge plants.

The filter medium or packing may be any suitable material although graded crushed rock of 2" - 4" size has been used conventionally. The depth of the rock bed may range from 3 feet to 8 feet, with the depth being governed by the soil bearing characteristics. Synthetic media are now available which are much lighter in weight than rock and it is possible to construct filters of up to 50 foot height. However, the costs of the plastic media tend to be high.

Trickling filters have not been used extensively in Canada on industrial waste applications, because the treatment efficiency tends to be poor during cold weather periods. However, the new plastic media allow for more compact, enclosed designs and the use of the filter may increase.

(b) Anaerobic Biological Treatment Systems

Anaerobic biological decomposition occurs when

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organic wastes are converted to gases (methane and carbon dioxide) in the absence of oxygen. The conversion of organic compounds to methane gas yields very little energy resulting in a slow growth rate and a relatively small yield of biological solids or sludge. The rate of reaction of the process can be increased by raising the temperature and it is possible to obtain 80 - 90 percent conversion of organics to gas. The methane gas can be collected and utilized to provide heat for the process.

Two types of anaerobic process systems are commonly encountered:

(i) the anaerobic lagoon
(ii) the digester

Of these, the anaerobic pond is the system most commonly used in the treatment of industrial wastes. With the digester being used almost exclusively as a method of stabilizing the sludges generated by aerobic treatment systems operating on municipal and industrial wastes.

(i) <u>The Anaerobic Lagoon or Stabilization Pond</u>

An anaerobic lagoon is designed to give a minimum surface area-to-volume ratio which provides maximum heat retention and minimum oxygen transfer. The waste

loading to the pond is such that anaerobic conditions prevail throughout the liquid volume. The following table presents some of the common design parameters for anaerobic lagoons:

- Depth, ft.	8 - 10
- detention, days	30 - 50
- BOD loading lb/acre/day	300 - 500
- percent BOD removal	50 - 70

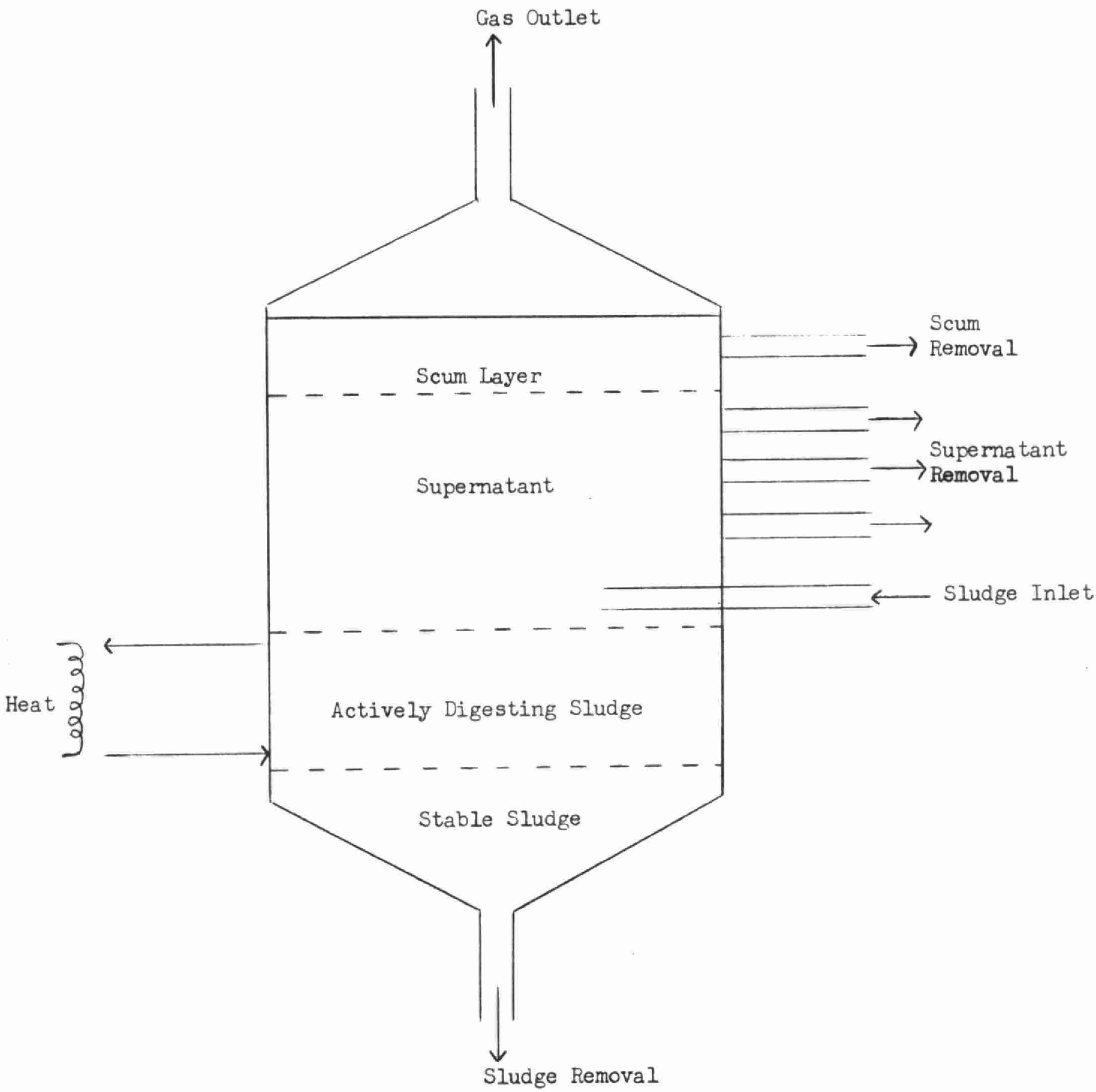
(ii) The Anaerobic Digester

Fig. XVII shows a schematic of a typical digester.

Digester temperatures are normally maintained in the range of 85^{o} F to 100^{o} F and pH is maintained near the optimum of 7.

Certain concentrated industrial wastes can contain materials that are toxic to the digestion process. These can include most of the metallic ions, particularly the heavy metals, ammonia, sulphides and numerous organic compounds. If digestion is being considered to treat a certain waste, the possibility of toxic effects should not be overlooked before a decision is made.

FIGURE XVII
ANAEROBIC DIGESTER



(c) Irrigation

A further method of biological treatment that is relatively cheap and convenient if land is available is irrigation. As the name implies, irrigation involves the distribution of wastes over the land such that the liquid will percolate through the soil and be treated by the soil bacteria. It can be practiced in a number of ways depending on the type of wastes, the type of soil and the topography of the land:

(1) Spraying over relatively flat land by the use of irrigation type spray nozzles.
(2) Distribution of the waste over sloping land which runs off to a natural watercourse.
(3) Disposal through ridge and furrow irrigation channels.

Irrigation treatment methods can only be used during the warm weather and in Canada this means approximately 6 - 8 months of the year. Spray irrigation is the most commonly used in Ontario and it finds application in the Dairy and Vegetable Processing Industries. Storage facilities must be provided for the wastes for that period when spraying is not possible.

A crop cover of grass, clover or other vegetation

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is usually grown to provide a certain amount of retention and to maintain porosity in the top soil layers. Care must be taken to ensure that direct contamination of the groundwater does not occur - particularly if there are wells in the vicinity.

Table C shows some typical data pertaining to spray irrigation systems:

TABLE C

Spray Irrigation of Industrial Wastes

Waste	Application rate USgpm/acre	Ave. loading: lb BOD_5 /acre/day	Ave. loading: lb SS/acre / day
Tomatoes	100	250 - 300	200 - 250
Corn	150	864	500
Cherries	100	800	654

To avoid clogging of nozzles, large suspended solids should be screened from the wastes prior to discharge. Deviations of pH from the neutral point of 7 could prove harmful to the cover crops and high dissolved solids in the form of inorganic salts can adversely affect the soil.

ION EXCHANGE

Certain synthetic resins have been developed which have the ability to exchange ions. This fact has been developed into a useful process known as ion exchange where, by the use of various resins, undesirable anions and cations can be removed from water or wastewaters. Cations (those with a positive charge) are normally exchanged for hydrogen or sodium ions whilst anions (those with a negative charge) are exchanged for hydroxyl ions, OH^-.

Examples of common ion exchanges can be represented by the following equations:-

$$Na_2R + Ca^{++} \rightleftharpoons Ca\ R + 2Na^+$$

And $$SO_4^= + R\ (OH)_2 \rightleftharpoons R\ SO_4 + 2OH^-$$

(R represents the exchange resin)

Since the reactions are all reversible, it is possible to regenerate the resins and in certain cases, recover the exchanged ion. For example:

$$2Na^+ + CaR \rightleftharpoons Na_2R + Ca^{++}$$

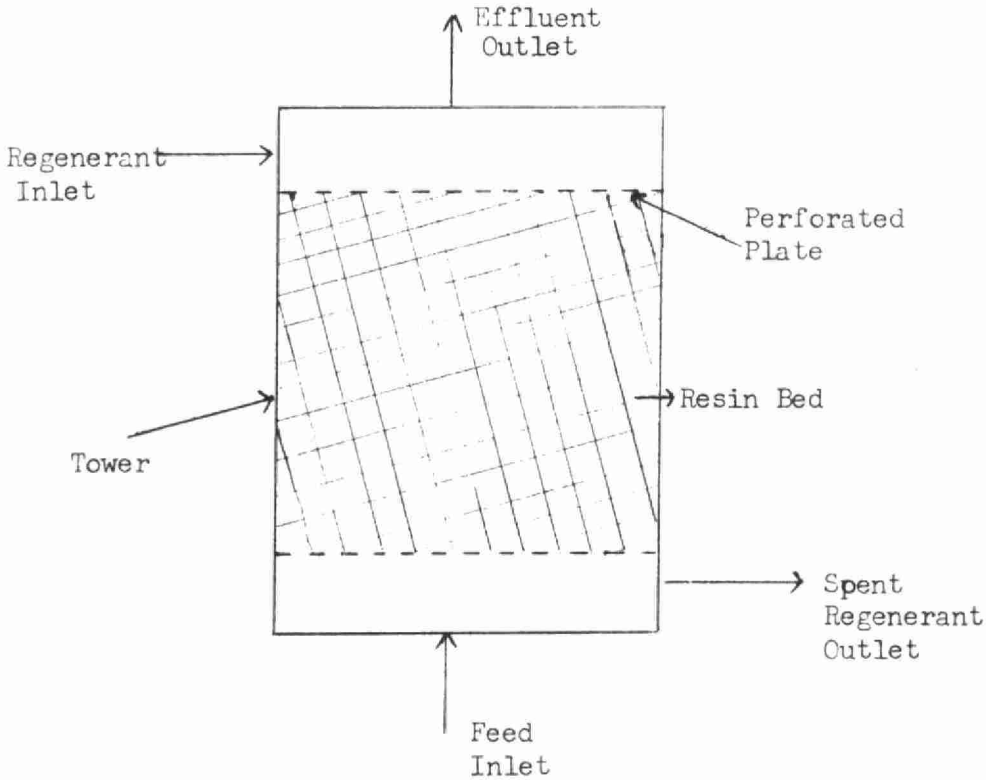
And $$R\ SO4 + 2OH \rightleftharpoons R\ (OH)_2 + SO_4^=$$

Regeneration is accomplished by the use of 5 - 10 percent solutions of brine and sodium hydroxide, respectively.

Ion exchange is accomplished in practice by passing the water of liquid waste through a bed of resin.

FIGURE XVIII

FIXED BED ION EXCHANGER



The capacity of the ion exchange material will vary with the nature and concentration of the ions in solution and the process is only normally economic if the resins can be regenerated. To ensure contact of the liquid with the resin and to minimize by-passing, the minimum depth of resin bed is maintained at 24 - 30 inches.

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Applied liquid flow rates may range from 2 - 5 gpm/ft^3 although care must be taken at the higher flow rates because 'break-through' occurs more rapidly. Break-through is defined as the point at which the contaminant appears in the effluent. At this point, the treatment is stopped and the resin bed is backwashed to remove dirt and to regenerate the resin. To maintain continuous operation it is necessary to have two or more resin beds.

ADSORPTION

The concentrations of some wastes are sometimes so low in industrial wastes that they are difficult to remove by conventional biological treatment methods. Examples of such materials are the non-degradable detergents (ABS), some of the cyclic organic compounds (Benzene derivatives, etc.), cyanides and gases such as chlorine and ammonia. Materials such as these can often be removed by adsorption on an 'active' surface. Activated carbon or charcoal is the most common material used.

The theoretical concepts of adsorption are too complicated to enter into here but it should be noted that waste waters usually contain more than one substance

and these substances will be competitively adsorbed until equilibrium conditions are reached.

In practice, continuous carbon filters, with detention times of less than 1 hour are used. The most economical use of carbon is generally achieved by multiple adsorption columns in series in which the first column is saturated when break-through occurs in the last column. The first column is then replaced with fresh carbon and becomes the last column in the series while the previous last column becomes the second last, and so on.

Materials can be recovered from the carbon by processes such as distillation or steam stripping, with the carbon being reactivated in the process. Economics will determine whether this step is performed.

Carbon filters are finding increasing use as a polishing mechanism following more conventional forms of treatment.

REVERSE OSMOSIS

Reverse osmosis is one of the most promising new

tools to appear in recent years with direct applications to wastewater treatment. Its major use is in the concentrating of dilute effluents which cannot be reasonably treated by other means.

The principles of reverse osmosis are best understood by examining first the principles of osmosis. Osmosis is a process that occurs in nature where two solutions of substances at different concentrations, separated by a "semi-permeable" membrane, will try to achieve the same concentration. This is done by solute (water) from the weaker solution passing through the membrane to dilute the stronger solution. The driving force by which this is accomplished is known as osmotic pressure. A semi-permeable membrane is defined as a membrane which will allow the solute to pass through but will not allow the material in solution to pass through.

Fig. XIX shows this process schematically.

To stop the process of osmosis it is necessary to apply a pressure to solution A that is equal to the osmotic pressure. If the applied pressure to solution A is greater than the osmotic pressure, solute will pass in

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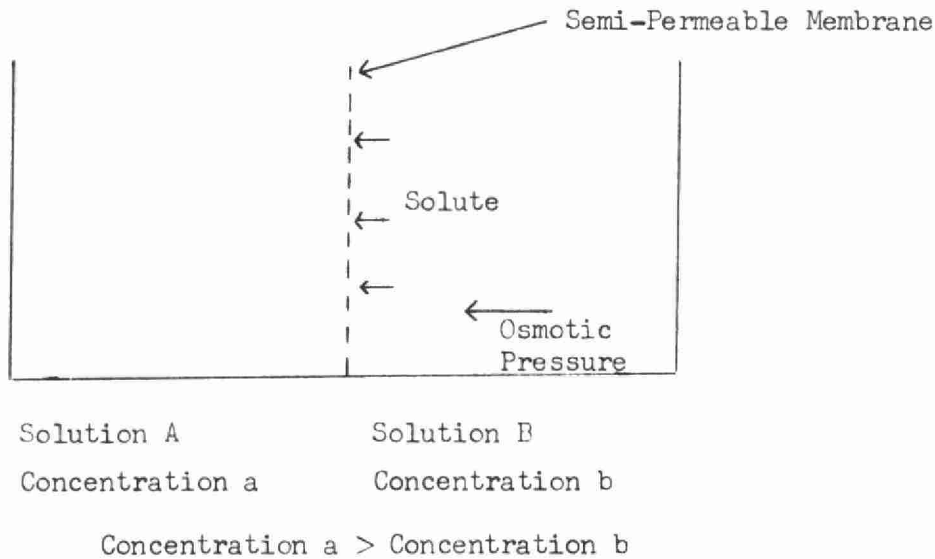
FIGURE XIX
OSMOSIS

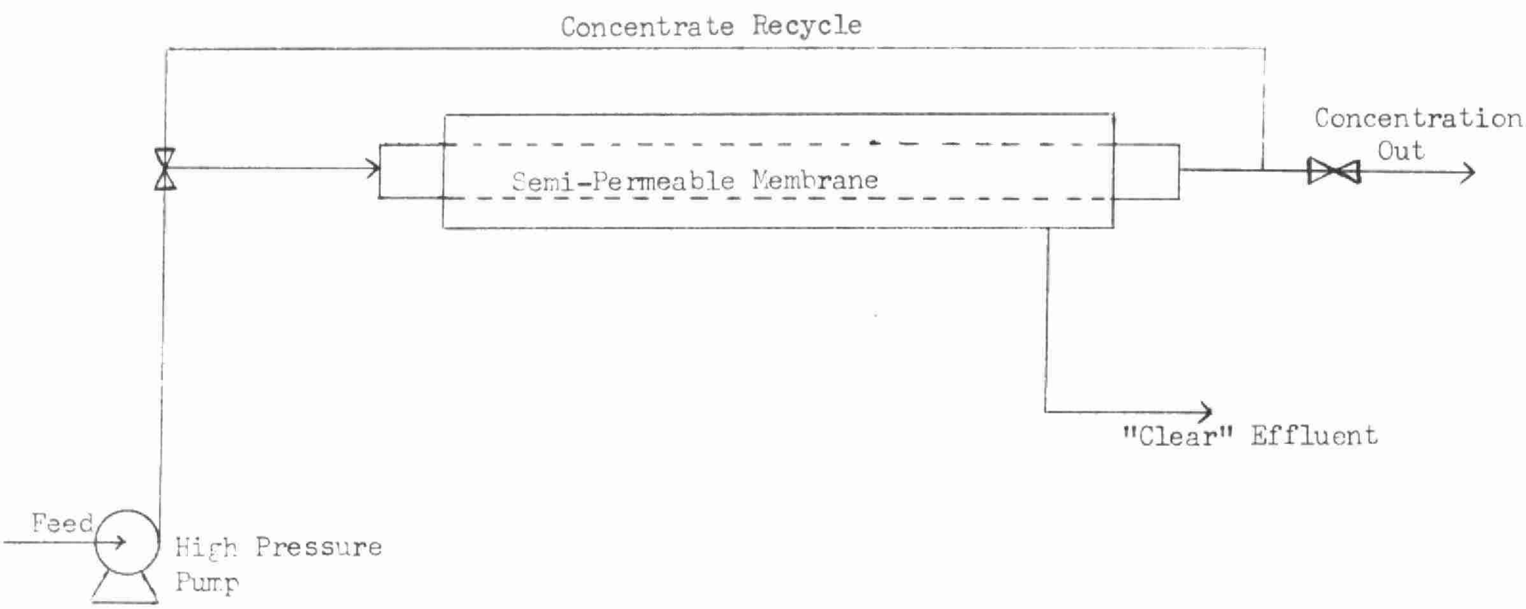


the reverse direction, that is, from Solution A to solution B. This then is reverse osmosis.

The major problem with reverse osmosis is to construct semi-permeable membranes that are able to withstand the pressures needed to effect meaningful transfer of solute and also to develop membranes that do not foul and become plugged too readily. Such membranes have been developed and the most successful

has been one in tubular form. Another problem is that although relatively "clean" water is produced by the process, at the same time a concentrated waste is also produced that requires treatment and disposal. In some cases this more concentrated waste can be evaporated for by-product recovery or incineration.

Fig. XX shows schematically a typical reverse osmosis application.



Costs of the reverse osmosis system are relatively high at present but it is certain that the process will find application in many areas where other forms of treatment will not produce the desired clean-up. Possible applications are in the Pulp and Paper Industry for dissolved solids and colour removal, in the chemical industry for dissolved solids removal and possibly in the municipal wastewater treatment field.

LIQUID - LIQUID SYSTEMS

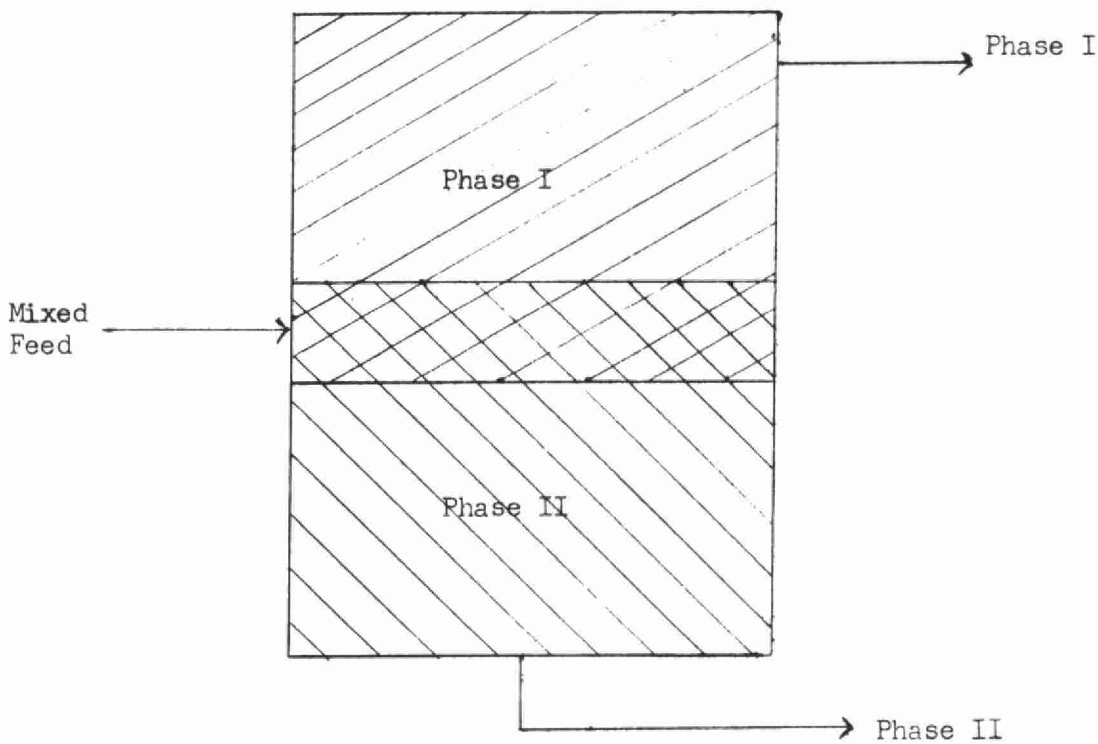
There are not many applications of liquid - liquid separation that are of interest to us from the waste treatment aspect but those that do exist are important. The prime example of liquid - liquid separation is the separation of oil and water and this is of particular interest because oils continually cause problems in sewers, sewage treatment plants and rivers. Other applications are the separation of greases, the breaking of emulsions and the removal of heavier-than-water compounds that tend to collect in the low points of systems.

The simplest way to separate two immiscible liquids is the 'decanter'. In a decanter, sufficient detention time is provided to allow the liquids to separate cleanly into the two phases and the separated liquids can then be drawn-off from top and bottom. The decanter is only really useful where large amounts of both liquids are mixed and therefore has limited application in the waste treatment field.

Fig. XXI shows a simple decanter.

FIGURE XXI

DECANTER



(1) <u>Emulsion Breaking</u>

When two immiscible liquids are finely dispersed one in the other, the resulting mixture is known as an emulsion. The emulsions most frequently encountered are composed of oil and water and the oil may be dispersed in the water (the usual case) or the water may be dispersed in the oil. If the emulsion is to be stable, a third component, the <u>emulsifying agent</u>, must be present. Soaps, detergents and a variety of naturally occurring

substances are good emulsifying agents.

Water-in-oil Emulsions are quite common in the petroleum industry and can be readily broken down by heating, a process that occurs in the refinery in any case.

Oil-in-water Emulsions are usually milky white in appearance and are sometimes very stable and difficult to destroy. Destruction of the emulsion depends on treatment to inactivate the emulsifying agent. Inactivation can be accomplished in a variety of ways but economics usually dictate that it be done by pH adjustment or by the addition of coagulants such as alum, ferric chloride or lime. Experimentation will tell which is the best treatment method to adopt.

Once the emulsion has been broken, the liquids return to their normal immiscible states and can be separated by conventional means, for example by decanting.

(2) Oil Separation

The separation of oils and water is accomplished in practice by utilizing the density differences of oil

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and water to effect separation in a gravity separator. A gravity oil separator operates similarly to a gravity clarifier for solids removal except that the oil floats to the top and is skimmed from the surfaces as opposed to the solids settling down and being removed from the bottom as a sludge.

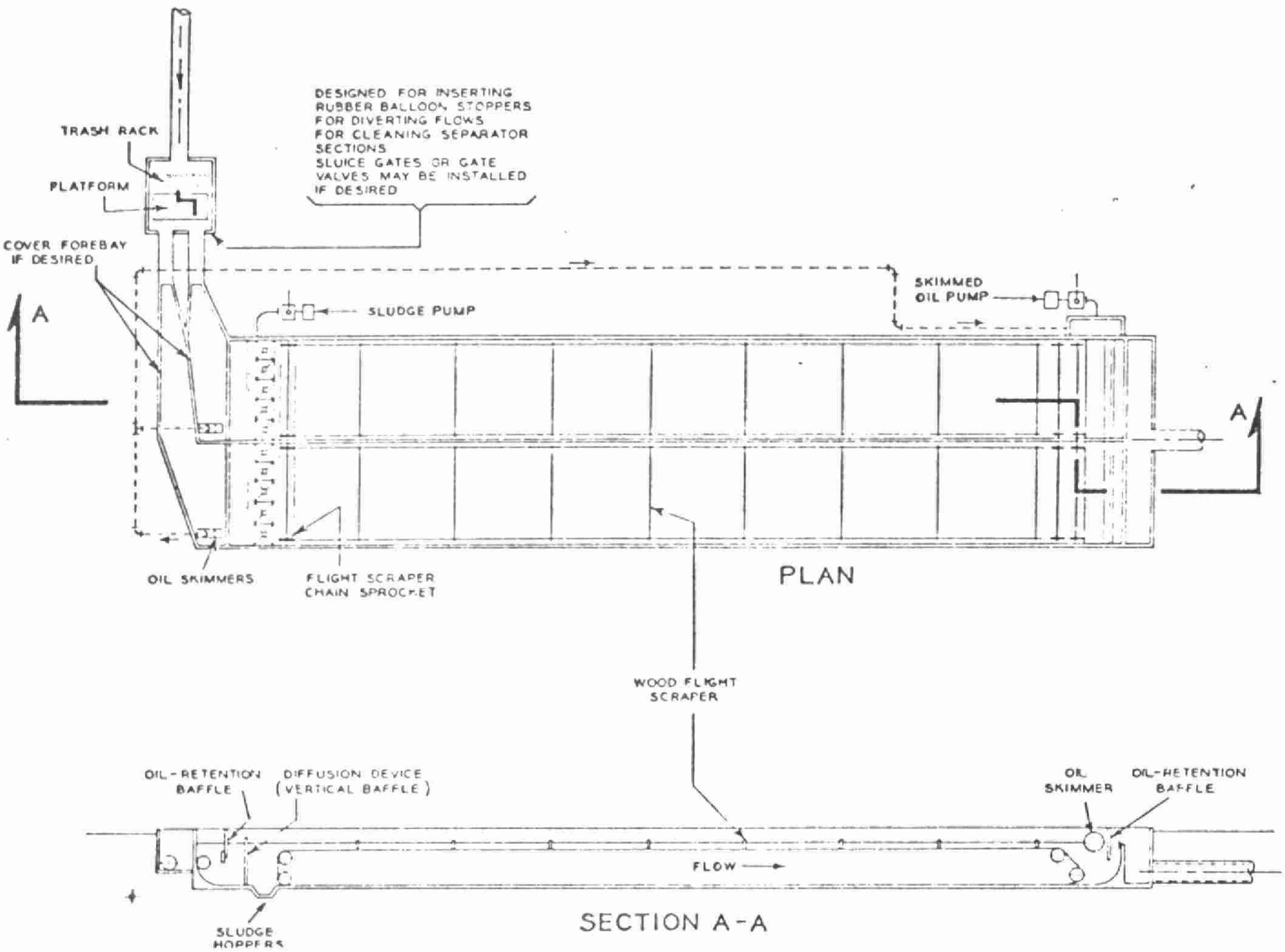
Standard designs for oil separators have been available from the American Petroleum Institute for a number of years but the designs are based on the recovery of oil for economic reasons rather than pollution control reasons and have not proved too efficient in some instances. Improvements have been made and are continually being made.

The main objective in an oil separator is to provide a stilling zone wherein the oil can float to the top under quiescent conditions. As a rough guide it has been found that if the velocity of the moving water is maintained in the range 0.5 - 1.0 feet per second, satisfactory separation is achieved.

Fig. XXII is a schematic of a typical oil separator.

FIGURE XXII

TYPICAL OIL SEPARATOR



The oil trap is a smaller version of the oil separator and is used to prevent the discharge of oil into sewers and storm sewers in areas where oil spills, leakage, etc. may occur. Certain papers later in the course will cover this area in greater detail.

(3) Grease Separation

Greases are substances that can cause a great deal of trouble if discharged to sewers, storm sewers, sewage treatment plants and every effort should be made to collect these substances for disposal in some other manner. Apart from the aesthetic problems, greases are also one of the main causes of pipe blockages.

A simple grease trap is very much like an oil separator, allowing the grease to float to the top whence it can be removed either mechanically or by hand. Continual or frequent removal of the grease is necessary if the trap is to function properly.

In certain industries such as meat-packing and rendering, the greases are often more difficult to separate and dissolved air flotation techniques are employed with continuous removal of the floated grease. The design

of the flotation system will generally be tailor made to the particular application but the principles will be similar to those discussed previously.

(4) <u>Heavier-than Water Compound Separation</u>

Most liquids of this type encountered have significant density differences from that of water and can be separated by gravity means. The design of equipment would be similar to that for clarification of suspended solids.

Where no substantial density difference exists, it might be necessary to resort to other types of processes that will be discussed next.

(5) <u>Other Liquid - Liquid Separation Systems</u>

Where emulsion breaking and/or gravity separation processes will not provide the degree of removal required, it will be necessary to resort to other physical processes that are generally costly. These will include stripping, distillation, absorption and evaporation. The design of systems of this kind is a job for a chemical engineer and beyond the scope of this presentation. However, you should be aware that

such means do exist to separate unwanted liquid contaminants from water.

Finally, as mentioned earlier, activated carbon adsorption might have application to problems of this sort and should not be overlooked.

GAS - LIQUID SYSTEMS

To complete this presentation, it is necessary to mention briefly gas - liquid systems, although the number of such systems that will be encountered will be minimal.

Foams can be considered to be dispersions of gases in liquids and are of great importance to regulating agencies due to the aesthetic nuisance they create. Foams, like emulsions, need the presence of a stabilizing agent if the foam is to persist for any length of time and we all know that soaps and detergents are capable of creating stable foams. Since the advent of biodegradable detergents, the foaming problems encountered as a result of detergent usage have decreased but many industrial wastes, including those from the pulp and paper, textile and meat packing industries can generate severe foaming problems.

There are two main methods by which foams may be destroyed. The first is the use of water sprays to break up the foam by mechanical action and dilution, and the second is by the use of anti-foaming compounds. Water sprays often tend to provide only a temporary

solution to a problem unless sufficient dilution water is added to render the foaming agents inactive. The use of anti-foaming agents should be approached cautiously as there could be some secondary effects associated with them such as toxicity, which might affect the operation of a treatment process or harm the aquatic life in a stream. Most anti-foaming agents tend to be relatively inert and can be used for most applications.

Other gas - liquid systems involve situations where a gas is in solution in the wastewaters and needs to be removed. There are not many examples of this type and generally it is necessary to resort to stripping or distillation to remove the offending gas. For example, ammonia present in relatively high concentrations can be stripped from solution by boiling or by air stripping.

CONCLUSION

Although it is recognized that this presentation only touched on many of the aspects of industrial waste treatment, the basic idea was to familiarize you with the types of treatment that are available to be applied to the many problems likely to be encountered. Most of

you will probably not require additional information on these systems but the interested reader is referred to the Appendix for further data.

THE DISPOSAL OF CONCENTRATED WASTES

The title of this paper, "The Disposal of Concentrated Wastes", was selected because it apparently fitted with the theme which was developed in the presentation on the methods of treatment of industrial wastes. You have been told that these treatment methods always end up by producing a concentrated waste, liquid or solid. It is not that simple. Unfortunately, there are complications, but before giving some examples of why this discussion should not be confined to concentrated wastes, we should examine some fundamental questions.

First, what is waste?

Our definition is that waste is any material which the owner considers will cost him more to keep than to discard.

The cost in this case is not necessarily purely financial; it may comprise a penalty in terms of time or effort, or of nuisance or hazard, including health hazards.

Until recently, consideration of the cost to the community or the environment of discarding waste was not taken into consideration; to be quite fair, it was rarely considered even by the designers of treatment

plants. An obvious instance is municipal sewage, where until recently multi-million dollar plants were designed for treatment, but little provision was made for the disposal of sludge.

It would certainly simplify matters if all industrial processes, and treatment processes, automatically resulted in a concentrated sludge. This, of course, is not the case.

At some stage in the design of a plant, a decision must be made whether the waste should receive further treatment or be discarded. What factors are involved in this decision?

Fairly obviously, the most significant factor depends upon what alternatives are available. If the waste can be dumped into the nearest ditch with impunity, there is little incentive to spend money on further treatment.

Without going into detail at this stage, there are in practice a number of valid reasons, from the operator's point of view, why further in-plant treatment should not be given, and the surplus waste hauled away for disposal. This is the point where the responsibilities, and problems,

of the Waste Management Branch of the MOE begin.

Before going into detail on the various solutions to these problems, the functions of the Branch, its Legislation, and its relationship with other Branches within the Ministry will be described briefly.

The wastes for which we are responsible can be separated into six major classifications, with widely differing hazards, problems, and solutions.

These are:

(1) Municipal and industrial solid wastes;
(2) Liquid industrial wastes;
(3) Hazardous wastes;
(4) Agricultural wastes and sewage sludge;
(5) Abandoned automobiles;
(6) Litter.

For our present purposes, we are essentially concerned with liquid industrial wastes, hazardous wastes, and sewage sludge.

Very briefly, municipal and industrial solid wastes includes domestic and commercial refuse together with non-hazardous solid industrial waste. It is

generally collected and disposed of under the control of the Municipality where it is generated, and at present in Ontario, the disposal method is by landfill with a comparatively tiny percentage of waste incinerated.

The Branch is encouraging the introduction of more sophisticated treatment methods; for example the use of grinding prior to landfill now in operation at St. Catharines, and grinding prior to incineration, being tested in the S.W.A.R.U. Incinerator Unit at Hamilton.

Since this classification of waste is the one which the Branch was originally set up to deal with, and since in fact our philosophy in this regard provides some interesting parallels with those wastes in which you are more concerned, it may be helpful to explore this in somewhat greater detail.

The basic objectives of any waste management program are to ensure that the environment is protected, at the least possible cost to the public and at the same time conserving to the greatest possible extent the natural resources of the Province.

This policy has a number of significant implications. It cannot be implemented unless, in addition to the control

of the storage, handling, transportation, treatment and disposal of waste, attention is also given to the complete cycle of production, distribution and use of the materials which ultimately result in waste. We must therefore, consider such strategies as:

(1) Reducing the quantity of goods produced, and thus obviously reducing the quantity of waste resulting;
(2) Changing production methods or using alternative materials so that a smaller quantity of waste results;
(3) Utilizing material which can more readily be reclaimed or recycled when it becomes waste;
(4) Reducing the quantity of waste to be handled by separating some proportion at the point of use.
(5) Processing the waste at the point of use, or at some intermediate point to simplify its transportation and ultimate treatment or disposal;
(6) Planning waste management systems to enable large central treatment facilities to be established where sophisticated methods of separation, treatment and reclamation can be economically implemented.

A category of waste of greater interest to you is liquid industrial and hazardous waste. The bulk of the liquid waste produced in this category has a limited degree of potential hazard. However, the very fact that it is liquid poses a number of specific problems in its

handling, treatment and disposal.

Major industrial plants are required to install treatment facilities for their own wastes, and these are under the control of the Industrial Wastes Branch of the Ministry. However, some waste cannot be dealt with in this way for the following reasons:

(1) Lack of technology for treatment. An example of this is brine.
(2) Unless large quantities of one particular waste are being produced, the cost of in-plant treatment may be prohibitive;
(3) Even if in-plant treatment is provided, provision must be available to deal with the residue from this treatment - the concentrated wastes referred to in the title of the paper;
(4) No matter how well planned and well operated a facility may be, breakdowns do occur, which frequently involves the need for prompt disposal of large quantities of untreated waste.

What types of wastes are these?

Various classifications can be used, but the major categories will be:

(1) Paint sludges.
(2) Resin sludges.

(3) Solvents.

(4) Oily water mixtures, emulsions and sludges.

(5) Acidic wastes.

(6) Alkaline wastes.

(7) Plating wastes.

(8) Neutral Salts.

(9) Organic wastes.

A separate category might be made for dilute soluble salts such as brine.

The quantities involved are extremely difficult to determine accurately, even after detailed market surveys. Certainly, in the Toronto Centered Region, more than 20 million gallons are produced annually with probably an additional 10 million gallons from Hamilton.

Before examining in detail the various alternatives available for treatment, mention should be made of the Legislative authority of the Branch in dealing with these matters. Legislative controls are exercised over two specific aspects, waste disposal sites and waste management systems.

"Disposal Sites" include treatment facilities as well as the ultimate disposal operations, and also include intermediate transfer facilities if these are provided.

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A "Waste Management System" includes the complete system of storage, collection, transportation, treatment and disposal of waste. The individual elements of the system are usually intimately interlinked and cannot be dealt with in isolation. However, for purposes of this particular discussion, "System" can be assumed to mean the handling and transportation of the waste only.

All operators, either of sites or of systems, must obtain a Certificate of Approval from the Waste Management Branch. A Certificate of Approval is issued for any period up to one year, when it must be renewed, and may be conditional upon the implementation of a program of improvement.

Dealing first with the collection and transportation system, a major problem results from the fact that the individuals and firms hauling the waste are essentially intermediaries between the producer and the disposer. Frequently, the smaller industries have no storage facilities to provide a full tank-truck load, with the result that one tank-truck might pick up wastes from a number of different industries in one trip. This has obvious hazards, and obviously limits the methods of treatment or disposal which can be employed, which is compounded by the lack of knowledge of the problems involved by the

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majority of haulers, and indeed by some of the industries.

This is, of course, particularly significant in the control of operations at a large central treatment plant for these wastes. It may well be necessary to require, by regulation, the issue of some form of bill of lading by the producer of the waste to the hauler, who would in turn provide a copy to the disposal site operator. This also implies the development of a classification system for wastes to provide information on the type adequate to determine the treatment required, the degree of any hazard involved, and any special measures which must be taken either in transportation, treatment or disposal.

Turning now to treatment and disposal, there are a limited number of general solutions:

(1) Disposal on to land.
(2) Disposal into land (into deep wells, caverns, or mines for example).
(3) Surface storage (lagooning for example).
(4) Permanent storage (by burial or in vaults).
(5) Physico-chemical treatment.
(6) Thermal treatment.

(1) <u>Disposal on to land</u>

In general, the types and quantities of liquid

waste which can be disposed of in this way are limited.

Spray irrigation or ridge and furrow disposal are feasible for some organic waste, although pretreatment by oxidation or anaerobic digestion is desirable to limit odours, and of course is necessary if, as in the case of sewage sludge, the waste is to be used on farm land as a soil conditioner.

Large quantities of oil are utilized on roads for dust control in the summer months, and this is an acceptable practice with the necessary controls to prevent runoff.

Limited quantities of a variety of liquid wastes can be disposed of on suitable solid waste disposal sites, though serious operational problems may result unless very carefully controlled. Moreover, sanitary landfills are normally designed deliberately to reduce the quantity of liquid which will percolate through the waste, thereby limiting the problems involved in leachate entering subsurface aquifers. An exception might be the use of a completed municipal waste disposal site with a substantial depth of waste and under drainage which will collect leachate for treatment.

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With this exception which will be discussed later, and re-use of processed organic waste as a soil conditioner, the disposal of industrial wastes onto land is in our view, an undesirable expedient with the potentiality at least for abuse and which should be phased out at the earliest opportunity. There are two problems related to the disposal of organic wastes onto land which should be mentioned. Organics are oxidized in the soil to nitrogen compounds, high levels of which in well water supplies may have direct public health implications. For this reason, controls over the disposal of sewage sludge or agricultural waste must limit the application fairly closely in relation to the nitrogen uptake of the crops grown. There is also at least a possibility that repeated applications of certain wastes may result in the concentration of heavy metals, which certainly warrants further investigation.

An inter-departmental committee has recently completed the preparation of interim guidelines for the use of processed organic waste as soil conditioner and these will shortly be incorporated as regulations under the Environmental Protection Act.

(2) <u>Disposal into Land</u>

At present in Ontario this is confined to deep well disposal, although it is possible that some use may be

made in the future of disused mines. In fact, this was given very serious consideration when large quantities of D.D.T. had to be disposed of following the Provincial ban, as was the possibility of burial in mine tailings areas.

Deep well disposal into suitable underground formations is an acceptable method for some wastes. However, suitable underground formations are limited both in geographical extent, and in their capacity to receive waste. In fact, they represent a resource which should be conserved by requiring surface treatment of all practicable wastes.

The formation now being utilized for this purpose in Ontario is the Detroit River sands in the Sarnia area which is between 600' and 900' deep. The only significant problem which has resulted from the use of these wells has been due to the large number of improperly plugged wells into the same formation in certain areas, particularly along the St. Clair River Valley. For this reason, it is proposed that all injection of waste by pressure into this formation should cease at the end of this year. The industrial wells used in the past have been closed down over the past two years as treatment plants were installed.

Certain wells into this formation make use of what are termed "lost circulation zones" which do not require pressure injection, and consequently offer little danger of pollution to other aquifers. These particular wells will be permitted to continue to accept all types of wastes until the end of 1973, and subsequently will be permitted to accept brine.

Only one well has been drilled for waste disposal into the Cambrian formation, which is at very much greater depth, and consequently has even more limited risks. However, there is no way of estimating the volume of waste that any particular well will take, if any, and the cost and risk of development of this formation has prevented its exploitation up to the present.

Recently amendments to the Environmental Protection Act provided Legislative authority to the Waste Management Branch to control this method of disposal. In practice the control will be exercised by an interdepartmental committee with representation from the Waste Management Branch, the Industrial Wastes Branch and the Water Resources Branch of the Ministry of the Environment, and the Petroleum Resources Branch of the Ministry of Natural Resources.

In addition, the amendment provided authority to require all disposal well operators to contribute, on the basis of quantity and type of waste injected, to a fund which will be used to provide alternative water supplies should any be made unusable due to deep well disposal operations.

(3) Surface Storage

This is essentially a transfer station operation, where wastes are stored temporarily until they can be disposed of.

Evaporation, in the climate of Ontario, is of no significance, and in ground conditions where seepage takes place, obviously there is a hazard of ground water contamination.

Storage lagoons for sewage sludge are used extensively during the winter months when weather conditions make it undesirable or impracticable to spread the waste on land.

Greater use might be made of lagoons for a number of organic wastes by the use of aeration, possibly only to the degree which would prevent odours during storage and subsequent disposal.

(4) Permanent Storage

This method is particularly applicable to hazardous wastes which require special precautions in handling or disposal, and for which treatment is impracticable.

Highly radioactive material is an obvious example, but the same practices are being followed with mercury, certain wastes from the petro-chemical industry and pharmaceutical wastes from laboratories and institutions. A comparatively small quantity of a very wide variety of materials, some of which may be extremely toxic, are involved in this case.

The specific method of disposal varies considerably, but in principle the wastes are stored to prevent the passage of water through them. Usually burial takes place at comparatively shallow depths above the maximum water table, preferably in clay soil. The trenches used may be additionally sealed with plastic or other liner and the wastes covered with earth, shaped and again sealed with plastic. Frequently the wastes are packed in drums, and occasionally by the double drum method, the annular space between the two drums being filled with concrete.

The Federal Government has recently proposed the construction of specially designed storage vaults for

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radioactive material.

(5) Physico-chemical treatment

The processes used are very similar to those utilized for in-plant treatment. They include neutralization and precipitation, the discharge of an acceptable effluent to a receiving body of water, or perhaps the concentration of the effluent for deep well disposal, permanent storage or thermal treatment, and frequently also result in a concentrated sludge which may require further treatment before disposal.

One recent development should be mentioned under this heading; the addition of chemicals to a waste with the object of solidifying it, so that it can be utilized for landfill. It is claimed that in many instances a non-leaching solid is formed, and the hardening process is controllable within limits, so that for example waste could be pumped from storage, the appropriate chemicals added, and the treated waste subsequently pumped to the point of disposal where the reaction would take place. Limited information is available on the comparative economics of this method of disposal, but it appears obvious that the more concentrated the waste, the more economic the process.

(6) Thermal Treatment

The most appropriate method of treating waste materials

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containing hydrocarbons or similar combustible components is by incineration. If the waste contains contaminants which may result in air pollution, sophisticated scrubber systems are necessary which in turn produce wastewater requiring treatment and disposal.

Use of a fluid bed reactor appears to offer the possibility of disposal not only of combustibles but of many of the sludges and concentrated wastes from other treatment processes; it also offers the possibility of comparatively simple reclamation of some of these materials. While all of the various methods described may have to be used for specific problems in specific areas, in all cases where there is a concentration of industry, in our view the best solution is the establishment of a central treatment facility. Due to the economies of scale, such a facility can provide the pollution control equipment necessary which would be exorbitantly expensive if provided by each individual industry producing waste. Moreover, in many instances one waste can be used to assist in the treatment of another, again reducing costs.

While such plants may vary substantially in the treatment processes used, they have a number of aspects in common. The design and operation of the receiving and storage facilities are critical. Drum handling

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facilities should be provided so that the contents can be unloaded into receiving tanks. Transfer from the receiving tanks to the tank storage farm or the treatments facility must not take place until adequate analysis has been carried out on the waste to determine its category for storage and treatment. An exception to this might be wastes hauled by the plant operator, where prior analysis has taken place and adequate controls have been developed to ensure uniformity of materials delivered.

It is obvious from the above that an integral part of the receiving and storage facilities must be a well equipped laboratory where the necessary analysis of the wastes can be performed both as a safety precaution and to determine the detailed treatment processes required.

Due to the very large variety of wastes which must be handled at such a plant, these processes may be complex. In addition to those earlier mentioned, inorganic salt solutions may be concentrated by evaporation, sludges may be dewatered by filtration, and humus filters have been suggested as a means of dealing with certain difficult organic wastes.

Generally, each particular waste material must be analyzed and treated with the appropriate reagents in

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successive steps. In many cases this treatment will not be final, producing a clarified liquor and a sludge, either or both of which may require further treatment or disposal at the site or at another site more suitable for the particular purpose.

In conclusion, the objectives of our activities in the field of hauled liquid and hazardous industrial wastes are:

(1) To ensure that treatment facilities are provided for all wastes where technologically practicable;

(2) To ensure that the haulage of liquid industrial wastes is carried out to the required minimum standards;

(3) To promote the improvement of management practices to reduce the quantity and hazard of such wastes at the source;

(4) To ensure that underground resources are conserved, underground formations of possible economic value are not impaired, and that no detrimental environmental effects result from the deep well disposal of liquid industrial waste;

(5) To assist in the development and improvement of procedures in the case of accident or emergency requiring the transport and disposal of contaminating and hazardous material.

CONTINGENCY PLAN

FOR

ONTARIO

What does contingency planning for spills mean? Why is it necessary? Who is doing it? Why and how must the municipalities become involved? These are some of the questions that will be discussed in the next few minutes and if at the end of this presentation you are left with a feeling that municipalities are expected actively to participate in contingency planning, the purpose of the paper will have been fulfilled.

What is contingency planning? Webster defines a "contingency" as "a chance, or possible occurrence" but in the context of spills, a contingency could more properly be called a probable occurrence. Last year in Ontario, over 400 spills were reported to the OWRC, and in about 60% of these there was, or could have been, municipal involvement. Contingency planning is the development of a format for action which must be carried out to ensure that the adverse effects of spills are minimized through implementation of a fast, effective response when the spill occurs.

Why are contingency plans necessary? After all, spills have occurred in the past and somebody usually cleaned up sooner or later. Perhaps it was you who cleaned up, perhaps it was somebody else, but the job

got done and even if it didn't, and there were some fairly serious effects, the situation cooled off rather quickly.

Please be assured that those days are gone and that now, and increasingly in the future, you will be asked to account for the actions which you did or did not take as the result of a spill. Legally, Section 32(3) of The Ontario Water Resources Act requires that a person who discharges a material of any kind, <u>and such discharge is not in the normal course of events</u> (i.e., a spill), shall forthwith notify the Ministry of the Environment.

When we learn of a spill, we ask a lot of questions and one of the first is "What are you doing about it?" If you don't have a contingency plan, you may be hard pressed to satisfactorily answer that question. If you don't have a contingency plan, the chances are that yourresponse will be relatively slow. This can result in increased environmental degradation since the spilled material will probably spread out into a larger area. In a more practical vein, clean-up costs will probably be far higher if emergency arrangements have to be made at the time of a spill.

What contingency plans currently exist, and what were they designed to accomplish? There is a great deal of contingency planning activity taking place at the present time and a description of some of them follows.

Existing contingency plans can be classified into levels depending on the size of the response that they are designed to elicit. Minor spills can be handled by a municipality's, an individual's, or a company's contingency plan; moderate spills require the resources of a co-operative or area contingency plan for control and clean-up; and a major spill is one that would require resources beyond the capability of a local co-operative, i.e., the Provincial Contingency Plan.

Beyond the Provincial Contingency Plan, there are Federal and International Contingency Plans. Truly massive spills requiring resources beyond those available to the Province, or spills which threatened to cross the international boundary, would require implementation of these plans.

No details will be gone into on the Federal and International Contingency Plans but the Province of

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Ontario Contingency Plan for spills of oil and other hazardous materials will be discussed in some detail. The purpose of the plan is to provide a format for:

(a) the discovering and reporting of spills;

(b) investigation to confirm and determine the magnitude of the spill;

(c) alerting and co-ordinating the resources necessary to control and clean up the spill; and,

(d) establishing financial liability for the cost of clean-up operations.

The Plan provides for the integration and co-ordination of resources provided by industries, various government departments, and others under the command of a pre-designated Ministry of the Environment official, to minimize the effects of a major spill of oil or other hazardous material which occurs in Ontario and which has the potential to pollute the surface or ground waters of the Province.

For the purpose of responding to major spills, Regional Operations Teams (ROT), which will serve as the technical team on the scene of the spill, are being established at eleven "high risk" areas in the Province.

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The ROT's will be made up of representatives from key Government Ministries such as Environment, Natural Resources, Transportation and Communications, etc. One ROT has been formed to date for the purpose of gaining experience, and it is expected that the remaining ROT's will be formed later this year.

To provide for co-ordination of the activities required to combat a spill, Ministry of the Environment personnel in each region have been predesignated as On-Scene Commanders (OSC) and their duty is to take charge of all activities related to the spill incident. The On-Scene Commander is supported by the ROT previously described. It is the OSC's responsibility in the event of major spills to implement as quickly and effectively as possible the contingency plan so that pollutional effects can be minimized.

Fortunately, major spills occur very infrequently, but this means that members of individual ROT's are unable to develop experience in handling large spills. A Provincial Strike Force, consisting of three or four representatives from Toronto staff of involved Ministries, is therefore to be established in the near future.

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As currently envisaged, the Provincial Strike Force will assume command of spill control operations during major spills and will work with the local ROT to effect the fastest possible clean up. Because the PSF will respond to all major spills a pool of expertise will be built up.

In the event of a major spill occurring in an area not covered by an ROT, or a moderate spill occurring where there was no ROT or Spill Co-operative, the Provincial Strike Force could be activated and would operate with staff from the Secondary Response Centre (SRC). These SRC's are to be established in "low risk" areas to provide a capability for investigation of spill reports and to carry out "first aid" pending arrival of the Provincial Strike Force.

There is one more key element in the Province of Ontario Contingency Plan and that is the Onterio Operations Centre (OOC). The OOC serves as a focal point for spill reports and its staff evaluates these spill reports to determine what action should be taken and whether the contingency plan should be implemented. The OOC is eouipped with a 24-hour telephone number (416) 965-2537 and after hours and weekends calls are answered by the Queen's Park Telephone Operators who

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will contact the Duty Officer within a short time.

The OOC maintains a list of resources available in the Province and also keeps abreast of currently accepted methods of spill control and clean-up. Staff of the OOC can provide valuable technical assistance on spill incidents, even if the Provincial Contingency Plan is not implemented.

How does all this affect you? A few minutes ago it was indicated that a moderate spill was defined as a spill incident of such a magnitude that the resources of a local contingency plan or co-operative would be required to control and clean up the spill. If there is no local contingency plan or spill co-operative, however, the response may be unsatisfactory for the reasons previously outlined.

The Ministry of the Environment, therefore, encourages the development of local contingency measures, either individually or co-operatively, and there is a good possibility that the Ministry will emphasize this aspect of its contingency planning activities in the future.

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What can municipalities do to minimize the adverse effects of spills within their boundaries? To begin with you must plan in advance the type of action that must be taken when a spill is discovered. You must determine who should be notified and who should be contacted to provide the necessary resources to contain and clean-up the spill. You must have some idea of the procedures used to minimize the adverse effects of spills including the use of barriers, booms, sorbents, oil removal methods, etc. You must know where to dispose of recovered material. You must know who to contact if additional aid is required.

In other words, you must make your own Contingency Plans and where possible you should participate with local industrial and provincial contingency planning groups to ensure that spills within you jurisdictions are handled in the most effective manner to minimize adverse environmental effects.

METAL INDUSTRIES
MANUFACTURING, WORKING, FINISHING

INTRODUCTION

The purpose of this paper is to review the industrial operations and the waste control and pollution prevention methods used in the metal manufacturing, working and finishing industry, with emphasis on those portions of the industry which give rise to liquid waste effluents and which are commonly found in many Ontario municipalities.

The Metal Industries will be discussed by first describing the industrial operations involved in metal manufacturing, working and finishing, then by identifying the various waste effluents with their sources within the plant, and finally by describing some of the pretreatment and treatment procedures which can be applied to these wastes before they are discharged to a municipal sanitary sewer or to a storm sewer or watercourse. It must be stressed that in any investigation of an industrial waste problem or survey of an industry, it is extremely important that the investigator go into the plant and examine the source or origin of the wastes. Only in this way can he form any idea of the magnitude and complexity of the problem, the chemicals used in the process which can become potential pollutants, the expected quantity of these contaminants, and the potential for any accidental or intentional discharge of batches of contaminated water wastes.

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It is not sufficient in an investigation or a survey, as opposed to routine surveillance work, to simply take a sample only at the plant outfall; it is also necessary to have some knowledge of the various industrial operations involved and for that reason, I will discuss in some detail the wet industrial operations in the metal industry and identify the various waste streams with their sources.

The metal industry is extremely varied, ranging from aluminum anodizing to zinc plating, from one-man shops to plants employing over 5,000 people, from the production of the basic metal to the assembly of the final product. Emphasis will be placed on only those parts of the Industry which are common to many Ontario municipalities and which do, or could, make use of municipal sewerage systems for waste treatment either with or without pretreatment at the industry.

PLANT PROCESSES AND OPERATIONS

Metal Manufacturing

(a) Steel

Steel making is a complex and fascinating process. Its products include steel strip, steel plate, steel rods and other shapes. Figure I illustrates the numerous steps in its manufacture.

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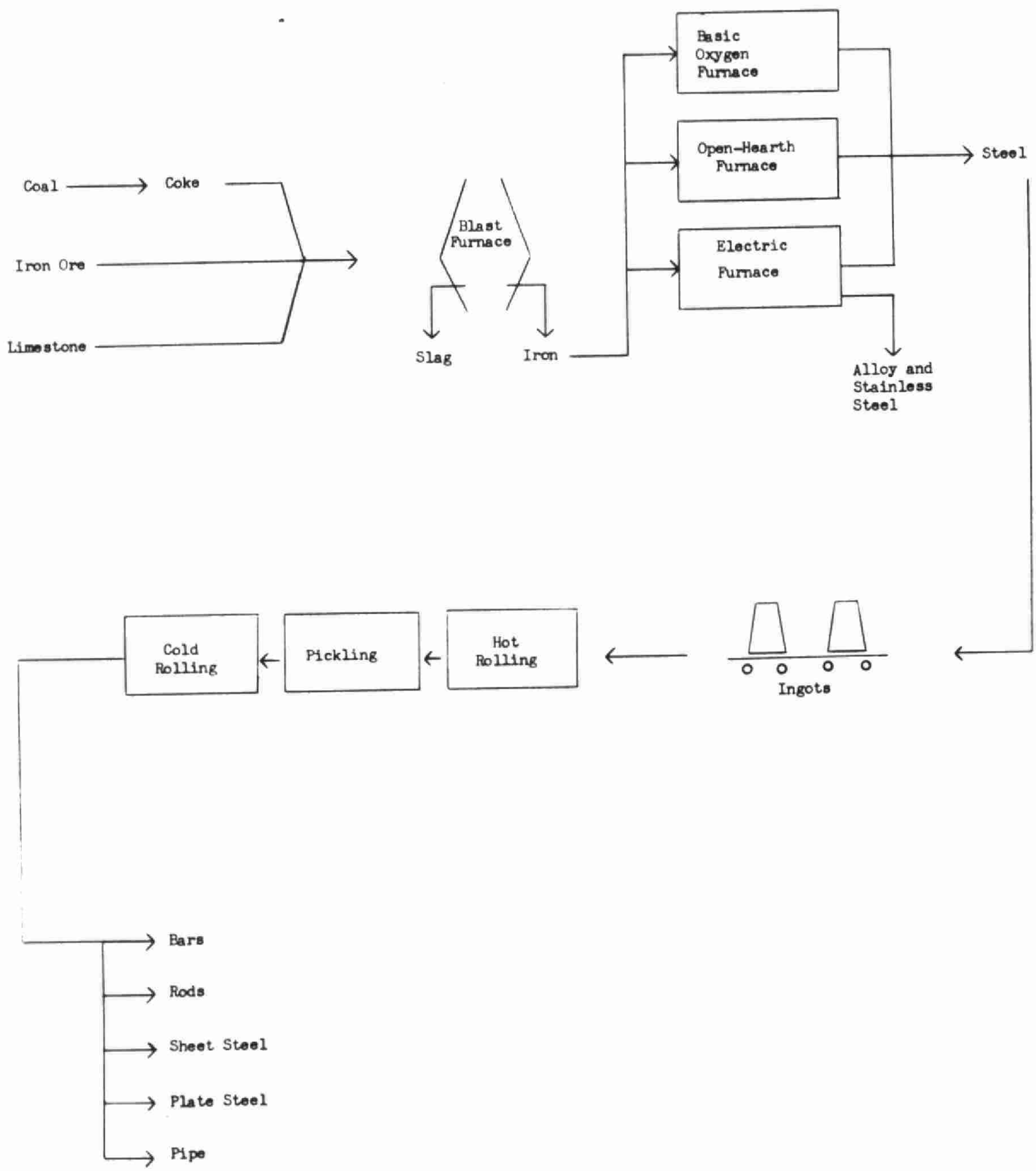
FIGURE I

FLOW CHART OF STEEL MAKING



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(b) Foundry Operations

The production of castings of iron or other metals is accomplished by remelting the metal and pouring it into molds. In the case of iron castings, "pig iron", the product of the blast furnace, and scrap iron are charged into a furnace known as a "cupola". The cupola is first charged with coke and alternate layers of metal, limestone as the fluxing agent, and coke as the fuel source. As the molten iron falls through the coke bed it is tapped-off as required. At the end of the charge, the slag, made up of the limestone and collected impurities, is removed and water-quenched. The molten metal is poured into molds and allowed to solidify. The molds are made of sand because sand is a heat resistant material. After a casting has solidified and cooled it is shaken from the mold. Binding material such as linseed oil, wheat flour or resins, sometimes phenolic in nature, are used to provide strength to the sand cores. The sand used in making the molds is partially reclaimed for re-use with burnt sand being discarded.

Metal Working

Metal working operations, whether performed on steel, copper, aluminum or some other metal, are ex-

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tremely varied and include rolling, descaling, machining, stampling and annealing, among many others.

(a) <u>Hot Rolling</u>

The usual first step is termed"rolling". In this step the raw material - iron, steel or other metal - is rolled into the sheets, pipes, rods, wire or coil.

In hot rolling, the metal ingot or slab is heated to make it mush more malleable and ductile so that it can be easily worked or rolled into the desired shape. The heat treatment applied forms a scale on the surface of the metal which must be removed before further processing.

(b) <u>Descaling</u>

The removal of the scale formed in hot rolling is usually performed by the use of high pressure water sprays followed by chemical or mechanical descaling. Chemical descaling is more effective and produces a cleaner product than mechanical methods. Dry mechanical methods such as sand blasting are preferred from a pollution control point of view and can be used depending upon the quality specifications of the product.

Chemical descaling of the basic steel (and other metals) utilizes either sulphuric or hydrochloric

acid in a process known as "pickling".

Pickling is performed either batchwise or continuously depending on the semifinished form of the metal. In the simplest method, bundles of scale or rust-encrusted steel are immersed in a vat of sulphuric or hydrochloric acid for a length of time sufficient to remove the scale while keeping direct acid attack on the steel to a minimum. The operation is characterized by a constant decrease of acid strength with a resulting increase in pickling time. This effect can be controlled temporarily by the periodic addition of fresh acid up to the point where ferrous sulphate starts to precipitate at which time the batch must be dumped. This method permits very efficient use of the acid, but the length of pickling time involved (30 to 50 minutes) is much greater than for other methods. A modification provides several vats in series arranged to dip the work in baths of decreasing acid strength and ending with one or two water rinse baths. This provides for efficient acid attack on the scale by contacting the heaviest scale with the strongest acid and providing a clean-up dip in a weaker solution. Continuous pickling is possible only in the case of strip or sheet steel where the end of the first strip

can be welded to the beginning of the next strip to form a continuous belt. The steel passes through several vats, arranged countercurrently as above. Continuous picklers operate rapidly and the total immersion time of the steel may range from 30 seconds to several minutes. This short reaction time is possible only at the expense of increased acid consumption. Solutions from batch picklers can often be discharged at a free acid strength of 1 to 2%, while the liquor from a continuous machine will seldom contain less than 5 - 7% free acid.

(c) Cold Rolling

After pickling, the material is cold rolled to further reduce the steel strip and remove surface blemishes. Heat generated during cold rolling is dissipated by flood lubrication using oil-water emulsions. After cold rolling, the steel may be given a temporary protective coating of grease if it is not immediately sent to further processing.

(d) Machining

Those operations which could be grouped under the general heading of machining include as examples grinding, drilling, boring, polishing, and cutting to give the metal its final shape. The raw material can be steel, iron, zinc, aluminum or other metals.

In these operations, a fluid is required at the tool-to-metal surface to provide lubrication, to remove the machined particles (the metal cuttings and filings), and to provide cooling. Straight "cutting" oil may be used but where high cooling capacity is required, water is used. To provide lubrication and also to prevent corrosion of the metal part, a soluble oil is added to the water to form an oil-water emulsion.

Metal Finishing

Finally, the metal-surface is handled or finished. This is accomplished by combinations of various operations depending on the desired properties of the final product. Included in these operations are vapour degreasing, alkaline detergent cleaning, annealing, a second pickling or sand-blasting treatment, buffing, galvanizing, electroplating, anodizing, chromating, phosphating, painting and when necessary on rejects or reclaim work, paint stripping, and metallic coating stripping.

(a) Mechanical Surface Preparation

Mechanical Surface Preparation includes polishing and buffing, abrasive blasting and mass finishing. Polishing and buffing are essentially dry operations. Abrasive sand blasting is either dry or wet. In wet blasting, the abrasive is suspended in water which is then forced by compressed air to nozzles

which are manipulated to remove surface metal contaminants. The slurry is constantly recirculated. Abrasive blasting is used for:

(1) removal of mold sand from castings, removal of scale, rust, paint and carbon deposits;
(2) roughening of surfaces for paint or adhesive application; and,
(3) removal of surface irregularities such as grinding lines, burrs, etc.

The operation is of significance from a pollution control point of view besides being more economical than pickling. It is an effluent-free process which can, under certain conditions, be substituted for pickling or chemical cleaning.

Mass finishing is a precisely-controlled method of processing small or large quantities of metal parts to remove burrs, sharp edges, tool marks, heat treat scale and to improve surface finish. It is generally termed "tumbling". In mass finishing, the parts are placed in a machine which imparts a revolving or vibrating motion between the parts and the medium. The medium is almost invariably water containing the burnishing compounds made up of abrasives, detergents,

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rust inhibitors, soaps, alkali cleaners and acidic salts.

Chemical Surface Preparation

The more common chemical surface preparation techniques include vapour degreasing, alkali cleaning and secondary pickling, all designed to clean the metal surface for subsequent operations. For subsequent electroplating, a very high degree of cleanliness of the metal surface is required and to accomplish this a multi-stage cleaning procedure is usually followed.

The types of soil which may be encountered are:

(1) oily soils such as mineral, oil-water emulsions, mill oils and oil-based rust preventives. Normally these may be removed by alkaline cleaners.

(2) semi-solid oils such as fats and waxes, and heavy rust preventive greases. These can be removed by heavy duty alkaline cleaners or by vapour degreasing.

(3) soilds containing solids such as buffing compounds, pickling smut residues, partially decomposed greases, dirt and rust.

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In addition to the mechanical methods, there are three types of soil removal techniques employed to remove the unwanted matter from the metal surface, namely:

(1) vapour degreasing

(2) alkaline cleaning

(3) pickling and acid dipping

(1) Vapour Degreasing

The process of vapour degreasing is accomplished by suspending the work to be degreased into a container in which a chlorinated solvent, usually trichloroethylene or perchlorethylene, has been vapourized. The hot vapours condense on the cooler metal parts and dissolve the greases, oils and waxes. In addition to the vapour phase, most degreasers combine one or all of the following methods: (a) immersion in boiling liquid, (b) immersion in a warm liquid, and (c) spraying with a clean solvent. The vapourized solvent is condensed and re-used. When the solvent becomes contaminated it can be recovered by distillation. Under no circumstances should the solvent be allowed to discharge to a sewer. The degreasing unit is equipped with a water-cooled cooling jacket or cooling coils to control the vapour.

(2) Alkaline Cleaning

This operation employs surfactant soaps and synthetic detergents and alkaline salts such as sodium hydroxide (caustic soda), trisodium phosphate, sodium polyphosphates, and sodium tetraborate (borax).

Methods of cleaning include soak tank cleaning or pressure spray cleaning followed by one or two stages of rinsing, with a still hot water rinse and a running cold water rinse or a spray rinse to remove excess alkalinity.

(3) Pickling and Acid Dipping

This process employs acids or strong oxidizing agents. Secondary pickling and/or acid dipping are utilized to produce a clean bright finish on the metal part. The operation removes smut on the metal surface produced during alkaline cleaning and the metal oxide coating or film produced during heat treatments of the metal.

Different formulations of pickling solutions and acids are used for different metals. Chemicals that can be used in various combinations in aqueous solutions are:

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(1) hydrofluoric acid
(2) nitric acid
(3) sulphuric acid
(4) phosphoric acid
(5) acetic acid
(6) hydrogen peroxide
(7) chromic acid
(8) sodium cyanide
(9) sodium dichromate
(10) citric acid
(11) potassium nitrate
(12) oxalic acid
(13) potassium permanganate

Plating

The plating industry which uses concentrated metal- bearing electrolytes, cyanides, alkaline cleaners and acids is a major source of effluent contamination. Waste effluent streams result from running rinses, floor spills, leaks, and deliberate dumps. The metals most frequently encountered are chromium, nickel, copper, zinc, cadmium, tin, silver and a small amount of palladium and other rare metals.

(1) Cadmium Plating

Most of the cadmium plating operations utilize a

sodium cyanide-cadmium oxide bath. Some cadmium barrel-plating operations use a cadmium fluoroborate-cadmium metal bath.

(2) Chromium Plating

A common formulation for chromium plating uses chromic acid (CrO_3).

Decorative chromium plating provides a non-tarnishing film over a copper-nickel or a nickel base.

Hard chromium plating is applied for functional purposes and the chief difference between it and a decorative film is the thickness of the coating.

(3) Acid Copper Plating

A typical formulation for an acid copper bath contains copper sulfate and sulphuric acid.

(4) Cyanide Copper Plating

Cyanide copper baths are used because:

(a) they can be used for plating steel and zinc base die castings directly, whereas acid copper requires a cyanide copper strike prior to regular plating;

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(b) copper is plated from the cuprous or monovalent state, so that twice the thickness of copper will be deposited from the cyanide bath as from the acid bath for a given amount of electrical current.

The formulation uses: copper cyanide
sodium cyanide
sodium hydroxide
sodium carbonate

(5) Alkaline Non-Cyanide Copper Plating

The bath for this non-cyanide copper plating technique is cyanide-free and is becoming more popular because of the absence of cyanide resulting in a less severe waste disposal problem.

The bath contains copper pyrophosphate and potassium pyrophosphate.

(6) Nickel Plating

Some typical nickel plating baths may contain some of the following chemicals: nickel sulphate
nickel chloride
boric acid
magnesium sulphate
ammonium chloride
phosphoric acid

(7) <u>Palladium Plating</u>

Palladium baths may contain palladium as disodium palladium tetrachloride or palladium tetra ammonium dinitrate or palladium chloride along with other chemicals.

(8) <u>Silver Plating</u>

Silver plating baths may contain silver cyanide
copper cyanide
potassium cyanide

(9) <u>Tin Plating</u>

Tin plating baths may contain tin as:

stannous sulphate
phenol sulphonic acid

or stannous fluoroborate
metallic tin
fluoroboric acid (HBF_4)

or potassium or sodium stannate
potassium or sodium hydroxide

(10) <u>Zinc Plating</u>

Zinc plating baths may contain for alkaline zinc plating:
zinc sulphate
sodium hydroxide

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sodium cyanide plus other
salts

or for acid zinc plating:
zinc sulfate or chloride
sodium sulphate or chloride
magnesium sulphate plus other
salts depending on the plating
properties desired

Zinc cyanide baths are also used.

Special Surface Treatments

(a) Stripping

Stripping of metallic coatings on rejects or on reclaim material is usually accomplished by immersion techniques. Among the chemicals that are used depending on the metal to be stripped and the base metal are:

ammonium hydroxide
sodium hydroxide
sodium cyanide
hydrogen peroxide
hydrochloric acid
chromic acid
sodium sulphide
sulphuric acid
phosphoric acid
nitric acid

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(b) Colouring of Metals

An almost unlimited variety of colours and shades may be applied to metals by heat treatment, chemical dips and electrolytic processes. A variety of acids, salts and polysulphides are used in the process.

(c) Chromate Coating

Chromate coatings are produced non-electrolytically on zinc, cadmium, aluminum, copper, brass, bronze, silver and magnesium.

The purposes of chromate coating are:

(1) for corrosion protection

(a) as final finishes

(b) as bases for paints and other organic finishes

(2) as decorative finishes

The chromate chemical bath is an acid solution containing hexavalent chromium compounds and certain inorganic or organic compounds, known as activators.

(d) Phosphating

Phosphate coatings are transformations of metal surfaces into new surfaces having non-metallic and non-conductive properties. They are used:

(1) to precondition surfaces to receive and retain paint and to protect surfaces against underpaint corrosion.

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(2) to prepare surfaces for bonding with plastic coatings

(3) to improve corrosion resistance by providing a good base for waxes and rust-preventive oils.

In phosphating, the phosphate combines with the metal of the part to form an integral metal-phosphate coating bonded to the base metal.

A phosphating cycle can consist of:

(1) clean to remove soil

(2) water rinse

(3) water rinse

(4) zinc phosphate (or iron or magnesium phosphate)

(5) rinse water

(6) chromic-phosphoric acidified rinse

(7) dry off

(e) Aluminum Anodizing

Aluminum anodizing is a process providing an oxide coating on aluminum parts as a protection against abrasive corrosion and for paint bonding. The process uses either chromic acid or sulphuric acid solutions to oxidize the surface layer to aluminum oxide. The usual cleaning and water rinsing procedures are used.

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(f) Painting

Ordinary spraying of paint is probably the most common form of paint application. Here the paint is simply sprayed onto the metal parts as they move through a specially constructed spray-paint booth. The back-wall may be a water-wall using recirculating water from which accumulated paint wastes must be removed after a few weeks' use.

Dry booths using back-walls of straw have been developed. Here the straw is removed for disposal in a land-fill area or by incineration, thereby overcoming a potential water pollution problem. Electrostatic painting results in a much more efficient use of paint with dramatically less paint loss to the extent that a water-wall can be dispensed with. In the process, the paint is given an electrostatic charge and sprayed onto the metal parts which have been given the opposite charge.

Paint stripping may be accomplished by mechanical methods such as sanding, scraping or burning which generates no water effluent for disposal.

Chemical stripping is presently much more popular,

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effective and economical. Organic solvents, alkalies and acids can be used. Stripping baths accumulate the removed paint in the form of a sludge which must be removed. The stripping bath becomes contaminated and at least part of the contents must be disposed of although the problem can be greatly reduced by decanting of clean liquid and desludging of the tank.

WASTE EFFLUENTS AND METHODS OF TREATMENT

Metal Manufacturing

(A) Steel

Wastes originating at an integrated steel mill include oils, both free and emulsified, suspended solids such as mill scale, pickling acids, phenols, ammonia, cyanides and sulphides which because of their nature and the quantity involved are not suitable for discharge to a municipal sewage system. Because of this, the basic steel manufacturing industry in Ontario has constructed and is operating its own private waste treatment facilities. These are quite specialized and will not be discussed here.

(B) Foundry Operations

The principal sources of liquid waste effluents at foundries are:

(1) Cupola waste gas scrubbing water for air pollution control purposes. The water scrubber removes

solid particulate matter from flue gases. The scrubbing water may contain 5,000 ppm or more suspended solids and 500 ppm particulate iron. Dry dust catchers and electrostatic precipitators can be used in combination with wet scrubbers. This water cannot be discharged directly to municipal sewers but must undergo treatment in some type of settling facility such as a clarifier to reduce the solids to more manageable levels. Effluent settling alone will usually not produce a waste effluent of a quality acceptable for discharge into a storm sewer or watercourse.

(2) Slag quench water. The hot slag is cooled by direct water quenching. Although most of the water and, indeed, all of the water if controlled properly, is evaporated, any excess may contain sulphides, particulate solids, iron and will be alkaline.

(3) Uncontaminated cooling water used to protect the walls of the cupola. The water does not contact the raw material or product and may be discharged directly into a storm sewer or watercourse.

(4) Sand transporting and sluicing water. The molding sand, after use, is reclaimed for reuse. Modern sand reclamation methods are completely dry operations using no water and consequently, produce no liquid waste effluent problem but many foundries still use wet

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slurrying methods for handling and transporting the sand. The burnt or waste sand slurry, besides containing large quantities of readily settleable solids, also contain certain organic materials and may contain phenol from the binders used in the casting operation. The waste, after pretreatment at the industry for the removal of solids, can be discharged into the municipal sanitary sewers for treatment of the organic and phenolic compounds. The optimum and preferred solution to the problem, of course, is the use of dry sand handling and reclamation procedures.

Metal Working

(A) Hot Rolling

The lubricating oil used in the machinery of the hot rolls is a major contaminant. The oil lost by leakage and during overhauls and maintenance of the machinery can be and often is a significant quantity. The best method of treatment is to prevent the oil from entering the waste effluent flow. Water-cooled anti-friction bearings, without oil lubrication, should be used.

(B) Descaling

(1) Pressurized Water Spraying

The heat applied to the metal in hot rolling results in the formation of "scale" which is removed by high pressure water sprays. Most of the mill scale, being

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the oxides of the metal, can be removed from the water medium by settling in "scale pits" although the final effluent from a scale pit is not normally of a sufficiently high quality for direct discharge to a watercourse. Discharge to a sanitary sewer for final settling at the sewage treatment plant, if the volume of water is not a major consideration, could be acceptable. Filtration can be used as the secondary treatment method to produce a very good quality effluent removing both the remaining finely divided suspended solids and any traces of oil to produce a clear high quality effluent.

(2) Pickling

In the pickling of steel strip, plate or rods, two kinds of liquid wastes result; the concentrated spent pickling liquids, and the rinse waters. Both kinds of wastes are contaminated by dissolved iron salts (sulphates or chlorides) and by free acids, but in different concentrations. The iron content of the spent pickling liquid lies between 70,000 and 150,000 parts per million (ppm), the acid content between 6 and 15 percent. The rinse waters have concentrations of between 500 and 1,000 ppm iron and a free acid content of 5,000 ppm.

The treatment of pickle liquor falls into two categories: non-regenerative and regenerative. The

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regenerative methods are preferred from a pollution control point of view since the potential contaminants are recycled for a productive use rather than simply being discarded.

(a) Non-regenerative

Lime

The chemistry is simple:

$$FeSO_4 + H_2SO_4 + 2\ Ca\ (OH)_2 \longrightarrow$$

Iron Sulphate formed by the reaction of the acid on the scale	Sulphuric Acid	lime added for neutralization

$$\longrightarrow Fe(OH)_2 + CaSO_4 + 2H_2O$$

solid	solid	water

The reaction products, $Fe(OH)_2$ and $CaSO_4$, are relatively insoluble and after filtration, the clear effluent is generally acceptable for discharge to a watercourse. Settling can also be used but a difficult wet sludge disposal problem is presented. Small volumes (under 10,000 gallons per day) are easily

handled in batch-treatment plants while greater volumes are processed more conveniently in a continuous operation. In either case, the pH must be raised to approximately 9.3 to precipitate the iron hydroxide.

The neutralization of hydrochloric acid pickling liquor with lime or any other alkali is not recommended because of the high dissolved solids produced by the reaction:

$2HCl$ +	$FeCl_2$ +	$2Ca(HO)_2$	——	$Fe(OH)_2$ +	$2CaCl_2 + H_2O$
hydro-chloric acid	iron chloride	lime		solid	soluble

(i) Ammonia

Ammonium hydroxide has been used for neutralization but it suffers from a number of disadvantages.

(1) ammonium hydroxide is much more expensive than calcium hydroxide (lime)

(2) the products of the reaction, ammonium hydroxide and sulphate are very soluble resulting in a discharge of excessive dissolved solids and the nutrient ammonia to the watercourse

Neutralization using ammonium compounds is not recommended and, in fact, would not be approved by the Ministry unless other special circumstances ab-

solutely required the use of the compound.

(b) Regenerative

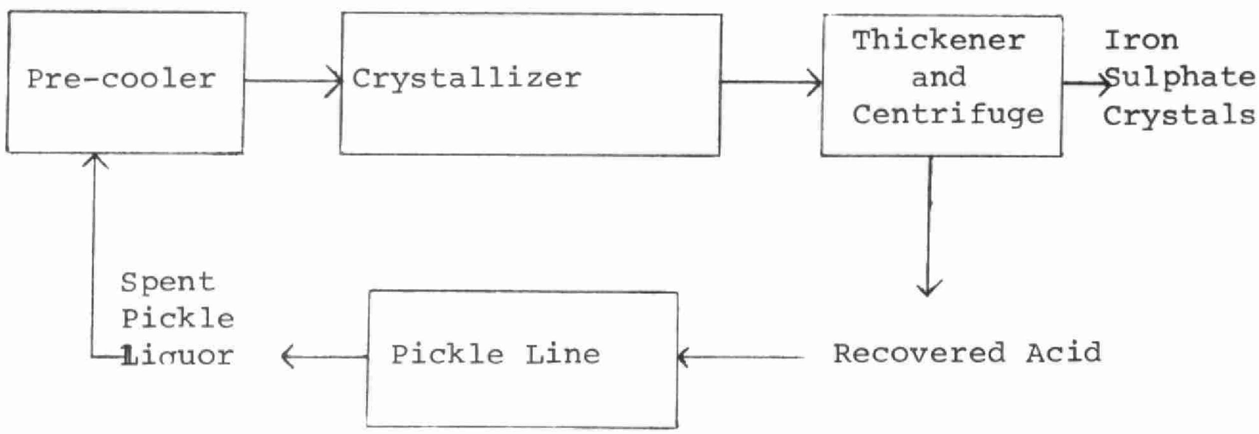
The regeneration of H_2SO_4 (sulphuric acid) and HCl (hydrochloric acid) with the production of iron sulphate or iron oxide for sale offers certain economic advantages in pickle liquor treatment over the non-regnerative neutralization processes described above. These systems have relatively high initial capital costs but low operating costs. The neutralization systems, particularly the batch system, require only a low initial capital cost but a high operating cost.

(i) Sulphuric Acid Recovery

As pickling proceeds, the build-up of dissolved iron salts formed by the reaction of acid and scale reduces pickling speed until an iron level is reached at which further addition of fresh acid cannot provide acceptable pickling conditions. Cooling of the waste sulphuric acid pickle liquors precipitates out the dissolved iron as ferrous sulphate crystals and allows the pickling ability of the remaining acid to be renewed. Operation of the system is as follows:

FIGURE II

FLOW CHART FOR SULPHURIC ACID RECOVERY



Cooling of the spent pickle liquor to 40°F takes place in the precooler and crystallizer. Crystals are maintained in suspension and are passed throug a thickener to a centrifuge which removes the dry iron sulphate crystals from the recovered acid. The recovered acid is returned to the pickle line.

In another system, the steel is pickled and passed to the rinse tank. The rinse tank is set up so that a set of sprays come on only when the steel is being withdrawn from the pickling bath. The contaminated rinse water is sent as make-up to the pickle tank and the acid strength of the pickle liquor is brought up to strength, leaving the iron concentration in the

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liquor as the only variable. When the iron strength increases to 9%, the liquor is sent to the Acid Recovery Plant where ferrous sulphate is crystallized out by cooling techniques and sold as a by-product. The reclaimed acid is re-used. This system eliminates the discharge of contaminated rinse water as well as reclaiming the pickle liquor.

(ii) <u>Hydrochloric Acid Recovery</u>

Regeneration of acid from waste hydrochloric pickle liquor employs fuel combustion to pyrolyze the iron chloride to iron oxide and hydrogen chloride gas followed by separation of the iron oxide by-product and by absorption of the gas to reform hydrochloric acid. Almost 100 percent of the total chloride content of the waste pickle liquor is reconverted to hydrochloric acid.

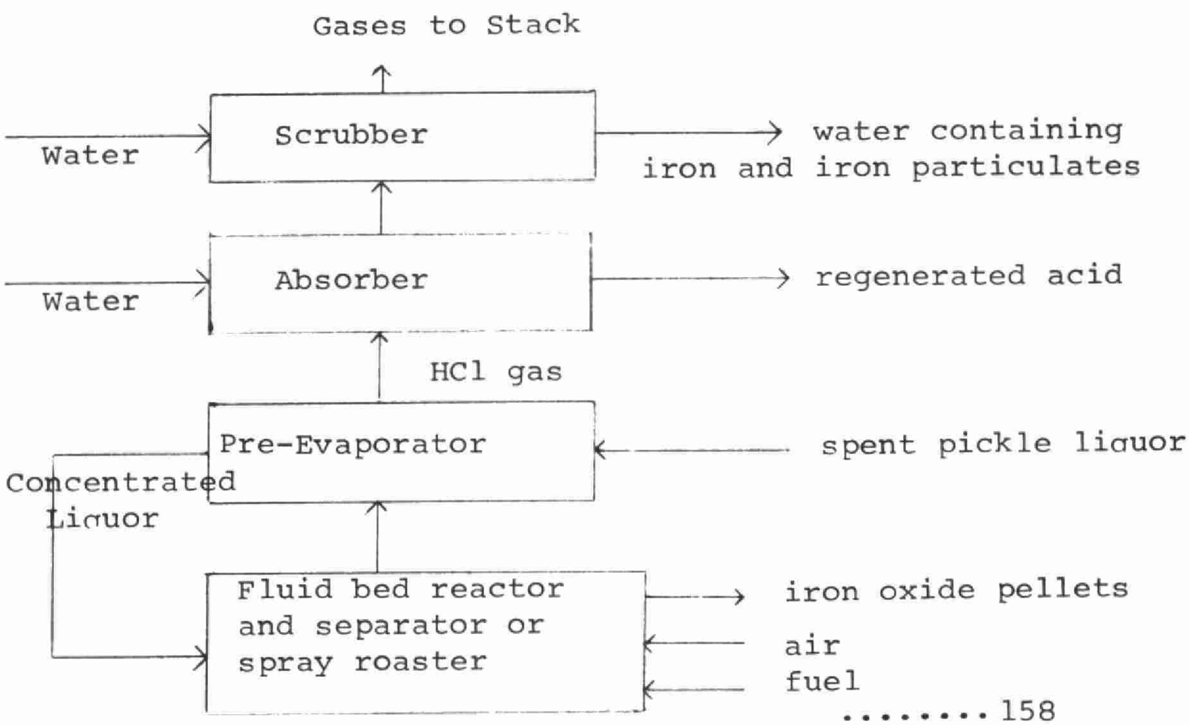

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FIGURE III

FLOW CHART FOR HYDROCHLORIC ACID RECOVERY

The spent pickle liquor is concentrated in the pre-evaporator and is fed into a fluid bed reactor. In another system, the liquor is fed directly into a spray roaster. There the complete vapourization of the water and decomposition of the iron chlorides into iron oxide and hydrogen chloride gas takes place at high temperatures (1500^{o}F). The hydrogen chloride gas is driven off along with some iron oxide particles entrained in the gas stream. The solid particles are separated in a cyclone as iron oxide pellets. The gases, after cleaning and cooling in the pre-evaporator, are passed to an absorption column in which hydrochloric acid is reformed and returned to the pickle line.

In a hydrochloric acid pickling system, the production lines must be vented for employee health reasons. The vented hydrochloric acid vapour is water scrubbed producing an acid waste effluent. In addition, the scrubber on the HCl Acid Recovery Plant system also contains certain quantities of acid and particulate iron. These wastes can be treated by neutralization, flocculation and settling or filtration, although a certain amount of dissolved chloride compounds will still be discharged to the watercourse.

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(C) Cold Rolling and Machining

Wastes from the cold rolling and machining operations are:

(1) Oil-water emulsions used as the coolant. This oil-in-water emulsion can be cleaned by filtering through paper or cloth, or by centrifuging, and is often recycled. Eventually, however, perhaps after 1 - 2 months or longer, depending on use and effectiveness of the reconditioning process, the oil becomes rancid because of bacterial contamination and it must be discarded.

(2) The oil adhering to the steel. The oil adhering to the steel is removed by a pass through an alkaline detergent cleaning solution followed by water rinses. The spent cleaning solution then contains quantities of emulsified oil.

(3) Leaks in the hydraulic systems and internal cooling systems of the metal-working machinery. The absence of sewer openings near the machinery and curbing around the machinery can prevent the oil from gaining access to the sewers.

(4) The oil-soaked metal turnings and filings. These can be centrifuged to remove the oil and the metal can be returned as scrap. Often this procedure is not followed and the storage and disposal of the oil-contaminated metal turnings can present serious

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problems at the dump site.

The treatment of oil-water emulsions consists of two steps, breaking of the emulsion and removal of the separated oil from the water. Breaking of oil-water emulsions is particularly difficult since emulsifiers and detergents are used expressly for the purpose of ensuring that the oil and water phases do not separate.

Emulsion breaking is accomplished by the addition of salts, acids, heat or a combination of these. In common use are calcium chloride, ferric salts, aluminum salts, sulphuric acid and hydrochloric acid. Acids are more efficient than salts although they are also more expensive. A combination of salts and acid is usually used in a treatment system. It is important to reduce the pH to below the free acid level or below pH 4, often down to a pH of 2. In a plant where pickling is also performed, some of the spent pickling liquor can be put to use in emulsion breaking.

Once the emulsion has been broken, the techniques used to remove free or unemulsified oils from water can be utilized. These techniques use the density difference between oil and water as the basic separation principle. Finely dispersed air bubbles to assist in

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bringing the oil to the surface for subsequent skimming can be used. In virtually all cases oily sludges accumulate on the bottom of the oil-water separator particularly in separators not kept in a state of agitation by the use of air-flotation techniques, and must be removed, usually by means of a built-in scraper mechanism.

Alternatively, flocculating agents can be used and flocculated solids allowed to settle out for subsequent removal. Oily wastes also containing paint wastes appear to be more amenable to flocculation and settling than to flotation.

The ultimate disposal of the collected oily skimmings and sludges can present a considerable problem. At a large automobile transmission manufacturing plant, the waste sludges, scum, and skimmings are dewatered in large "cookers" using indirect heating steam coils. Alum, used as the flocculating agent, is reclaimed by cooking the mass with sulphuric acid and it is re-used to flocculate the incoming wastes. Oil is also recovered. Other locations use large settling ponds in which the sludge has time to compact in the ponds from which it is periodically removed for land disposal. This is,

at best, questionable practice.

The best solution to the disposal of oily material would be reusing it as a fuel in the boilers of the powerhouse. However, this is not always feasible either because the plant has no oil-fired burners or the recovered oil is not of acceptable quality. Land disposal is not recommended because of the fluid nature of the material.

The solution to the problem appears to lie, for the present at least, in disposal by incineration. Oily sludges, whether or not combined with paint, solvent or similar wastes, can be disposed of by this method. There is a commercial incinerator near Sarnia accompanied by a satellite station in Windsor which will accept these wastes. Similar installations will be constructed in other parts of the Province in the future.

For an effective waste treatment system at any metal-working plant using oils or oil-water emulsions, the contaminated wastes must be segregated from all cooling water discharges and other uncontaminated flows. The reason for this is simply to provide a manageable oily water waste flow which will require a treatment system geared to the size of the oily water flow, not to the total water flow. Considerable

economies are achieved by an effectively segregated sewer system.

The breaking of oil-water emulsions is presently probably best accomplished by a batch treatment system rather than by a continuous flow-through system. The reason is that each batch can be treated as unique, having its own properties and its own best treatment procedure tailored specifically to that batch. In large metal-working and machining shops, there is considerable variety in the types of oil which are discharged in any given period of time. By using a batch system, simple laboratory tests can be run prior to full-scale treatment to determine the optimum treatment possible. Changes in the treatment procedure from batch to batch may include use of different chemicals to split the emulsion, different dosages, different retention times, or the application of heat. A batch system also lends itself more readily than a continuous system to a second treatment cycle if the results of the first treatment procedure are not satisfactory.

METAL FINISHING

(1) Mechanical Surface Preparation

Mechanical surface preparation procedures such as dry abrasive blasting produce no liquid wastes and are therefore preferred over pickling if quality

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specifications can be met by the operation.

Burnishing wastes must be treated for the removal of suspended solids by settling, or preferably, by filtration. Subsequent discharge to a sanitary sewer for further treatment of any organic soaps or detergents present is preferred to discharge to a storm sewer.

(2) Chemical Surface Preparation

Alkaline cleaning solutions must be treated for the neutralization of the solution and the removal of the soil, whether floatable greases or settleable dirt. Cooling of the solution in the settling chamber will often assist in congealing the greases and waxes present for removal by skimming from the top of the liquid.

The wastes from secondary pickling and acid dipping operations are treated as described in the section entitled "Pickling".

(3) Plating

(A) Reduction of Waste Strength and Volume

To indicate the variety of wastes originating from a plant engaged only in metal plating, the following typical flow charts for four very common plating operations are presented. All four and more could be carried out at a given plant at any given time.

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Copper Plating

alkaline cleaner

running rinse

5% HCl dip

running rinse

copper cyanide "strike"

running rinse

running rinse

copper pyrophosphate solution

running rinse

hot still rinse

drying

Nickel Plating

alkaline cleaner

running rinse

5% H_2SO_4 dip

running rinse

bright nickel solution

running rinse

soap dip

hot still rinse

drying

Chrome Plating

alkaline cleaner

running rinse

H_2SO_4 dip

spray rinse

chromium solution

still rinse

mist spray rinse

running rinse

hot still rinse

running rinse

hot still rinse

drying

Zinc Plating

alkaline cleaner

running rinse

5% H_2SO_4 dip

running rinse

zinc cyanide solution

running rinse

spray rinse

HNO_2 brightener

still dip

running rinse

running rinse

hot still rinse

drying

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From these flow charts it is clear that the character and strength of plating wastes vary considerably from day to day and from plant to plant, depending on production. Following are some typical plating-waste concentrations:

	Plant A	Plant B	Plant C
pH	3.2	10.4	2.4
Cu, ppm	16	19	35
Fe, ppm	3	11	4
Ni, ppm	0	5	19
Zn, ppm	0	0	82
Cr, ppm	1	7	100
Cyanide, ppm	0.2	6	15

In all plating plants, the wastes originate from essentially the same operations. After the work has been immersed in either a plating bath, an alkaline cleaner, a strong acid or a cyanide solution, the liquid material remaining on the piece must be rinsed off to prevent contamination of the succeeding chemical solutions. When the work is withdrawn from a particular bath, some of the solution from the bath adheres to the surface of the piece. This material, known as "drag-out" will contaminate the rinse waters with materials such as heavy metals, acids and cyanides which can range in

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amount from a trace to a value as large as 50 times that actually deposited on the work during plating. This drag-out value will depend on the shape of the piece being dipped, the amount of time the work is allowed to drain before going to the rinsing operation, and the viscosity of the solution. Other waste waters include those that result from batch dumps of spent acids, alkali cleaners and cyanide solutions that have to be replaced at fairly regular intervals. The electroplating solutions are usually not dumped because of their high economic value.

The first step in solving the waste disposal problem and sometimes all that is necessary to enable the plater to meet the local municipal sanitary sewer-use by-law limits is a lessening of the pollution load by reducing both the wastewater contamination and the volume of rinse water. The methods used to achieve these objectives are:

(1) good housekeeping practices
(2) chemical recovery
(3) better process control
(4) process chemical substitution
(5) water recycle
(6) rinse water control

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It follows that the smaller the volume of waste effluent to treat, the more economical will be the required treatment system. This is particularly true for batch treatment systems. Because the rinsing operations produce the greatest volume of wastewater requiring treatment, rinsing should be performed with the best possible water usage. The usual methods advocated include:

(1) minimizing drag-out contamination by withdrawing the work slowly from the solution and allowing it to drain over the tank

(2) using non-running reclaim rinses (drag-out tanks).

(3) controlling rinse water flows by conductivity cells

(4) using multiple counterflow rinse tanks

The first method is difficult to implement when dealing with manual operations and where employees are paid on a piece-work basis. The second method use of drag-out on still rinse tanks, is almost always employed where drag-out recovery is profitable. Its method of operation is shown in Figure IV.

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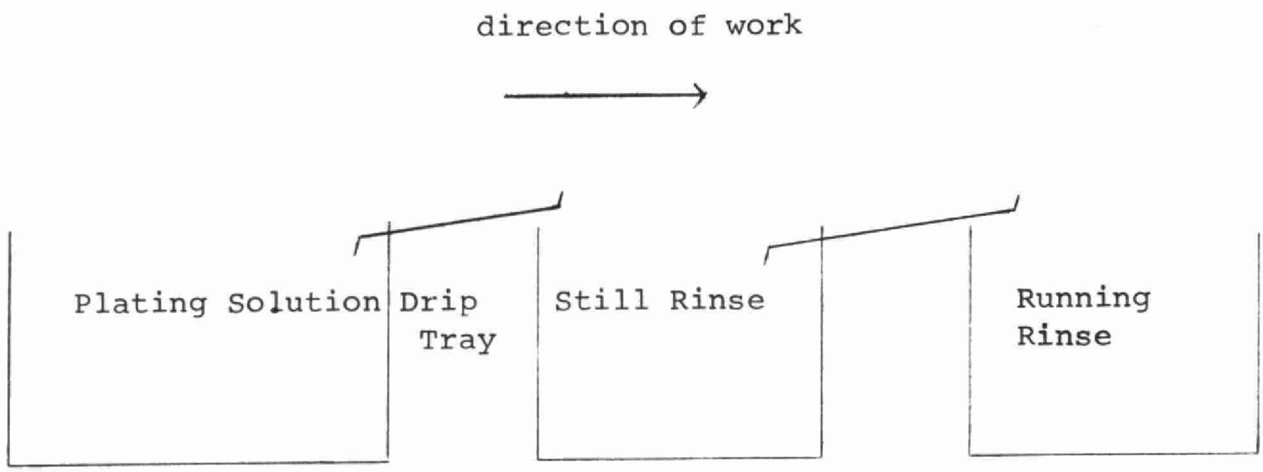

FIGURE IV

RECOVERY OF DRAG-OUT

Losses from the plating solution due to evaporation and drag-out are made up from the contents of the still rinse tank.

Conductivity control is achieved by using a conductivity cell to monitor the amount of dissolved solids contamination in a rinse tank and to add water to the rinse tank only when the dissolved solids contaminant level is above a pre-established level.

Counterflow rinsing consists of a system that utilizes several rinse tanks connected in series through which rinse waters flow in one direction while the work is rinsed in the consecutive tanks in the opposite direction. This reduces the volume of

rinse water required by making better use of the water. The first rinse contains some contamination but is adequate to remove most of the drag-out from the metal piece. The third or final rinse is clean and therefore can adequately provide a final clean water rinse to the piece. In the system illustrated in Figure V the water is reused twice, thereby lowering the total water consumption.

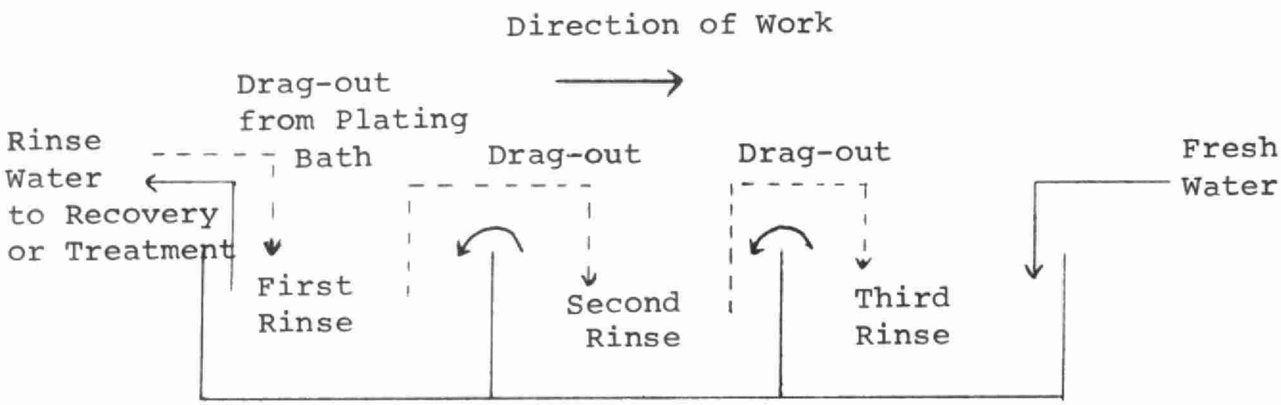

FIGURE V

COUNTERCURRENT RINSING

Figure VI shows from an actual case, the reduction in waste volume made by installing double and triple countercurrent rinses in place of single rinses.

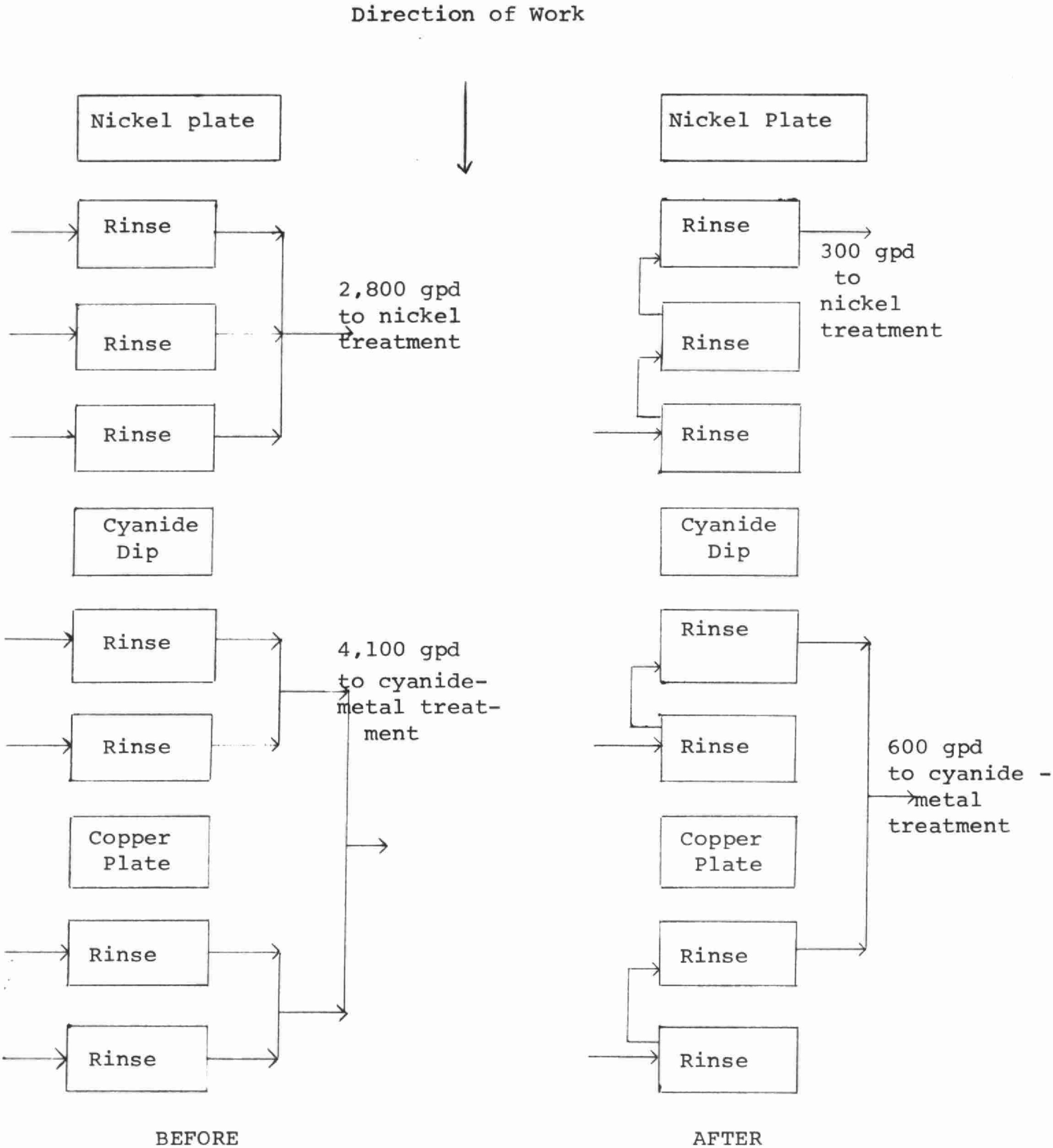

FIGURE VI

USE OF COUNTERCURRENT RINSING TO REDUCE WASTE FLOWS

Because of the low flow rates in a minimal water-use countercurrent rinse system, agitation must be provided in each tank to provide sufficient mixing of the water to ensure effective rinsing. This is accomplished by blowing air through a perforated pipe placed horizontally near the bottom of the tank.

Other methods to reduce flow and contaminants include:

(1) installing a gravity-fed, non-overflowing holding tank or pond to contain toxic materials which could or would otherwise be lost to the sewer by power failures, line ruptures or other accidental spills

(2) eliminating breakable containers for concentrated materials.

(3) using drip trays and shaking mechanisms to maintain as much of the drag-out in the plating tank as possible.

(4) using spray rinses or high-pressure fog rinses rather than high volume running water rinses.

(5) reducing drag-out and spills by hanging surfaces as nearly vertical as possible. Rack with the lower edge tilted from the horizontal in order that the run-off is at the corner rather than at the whole edge.

(B) <u>Waste Treatment Systems</u>

When everything has been done to minimize the

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volume of flow and contaminant concentrations, the selection of the treatment system can be made. The chemistry of these systems can be complex. The briefest summary follows:

(1) Lime or caustic soda is used to raise the pH for neutralization of acids or precipitation of metals in the metal hydroxide form.

Example: $\underset{\text{lime}}{Ca(OH)_2} + \underset{\text{acid}}{H_2SO_4} \longrightarrow \underset{\text{solid}}{CaSO_4} + \underset{\text{water}}{2H_2O}$

$\underset{\text{lime}}{Ca(OH)_2} + \underset{\text{nickel}}{Ni^{++}} \longrightarrow \underset{\text{nickel hydroxide (solid)}}{Ni(OH)_2} + \underset{\text{calcium}}{Ca^{++}}$

Lime is less expensive than caustic soda but is more difficult to prepare and handle. Sludges produced using lime are generally more compact than sludges produce using caustic soda. Optimum pH values for precipitation of the heavy metals are:

	Optimum pH
Lead (Pb++)	6.3
Trivalent Chromium (Cr+++)	6.5 - 7.3
Copper (Cu++)	7.1 - 7.3
Zinc (Zn++)	8.3 - 8.5
Nickel (Ni++)	9.2 - 9.4
Cadmium (Cd++)	9.7
Aluminum (Al+++)	5.2

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(2) An acid such as sulphuric acid is used to neutralize alkalies such as encountered in alkaline treatment and alkaline cleaning solutions.

(3) Cyanides are destroyed by oxidizing them with an oxidizing agent such as chlorine or sodium hypochlorite at a pH of 11. The cyanide is converted to CO_2 and N_2 when enough chlorine is added, when the pH is properly controlled and if the reactions are allowed sufficient time to go to completion.

The oxidation of cyanide to N_2 gas and carbon dioxide in the form of the bicarbonate is chemically very complicated but it is generally shown to occur in two stages as follows:

$$\underset{\text{sodium hypochlorite}}{2NaOCl} + \underset{\text{sodium cyanide}}{2NaCN} \longrightarrow \underset{\text{sodium cyanate}}{2NaCNO} + \underset{\text{sodium chloride (salt)}}{2NaCl} \quad (1)$$

$$\underset{\text{sodium hypochlorite}}{3NaOCl} + \underset{\text{sodium cyanate}}{2NaCNO} + H_2O \longrightarrow \underset{\text{sodium bicarbonate}}{2NaHCO_3} + \underset{\text{nitrogen gas}}{N_2} + \underset{\text{salt}}{3NaCl} \quad (2)$$

Combining the two, we obtain:

$$5NaOCl + 2NaCN + H_2O \longrightarrow 5NaCl + N_2 + 2NaHCO_3$$

An intermediate reaction in stage (1) above is the gas, cyanogen chloride, (CNCl) which is at least as toxic as cyanide itself. The conversion of cyanogen chloride to the much less toxic cyanate by

$$CNCl + H_2O \longrightarrow HOCN + HCl \quad \text{(pH dependent)}$$

is highly pH dependent and a pH of 8.5 to 9 or higher is essential for rapid conversion in about 7 minutes. The destruction of cyanates to N_2 gas and to CO_2 in the form of the bicarbonate is also pH dependent and at a pH above 10 will not take place. At a pH of 9 it theoretically requires about 15 minutes. At a pH of 9.5 about 10 minutes are theorectically required. These are theorectical numbers and many other factors play an important role in the rate of reaction. However, it is evident that it is extremely important to ensure that optimum pH values and adequate retention times are maintained in the reaction vessels.

(4) Hexavalent chromium is reduced to trivalent chromium under acid conditions using a reducing agent, usually sodium metabisulphite ($Na_2S_2O_5$) or occasionally SO_2 (sulphur dioxide gas) or ferrous sulphate. Because oxidation of cyanide requires alkaline conditions and reduction of chromium reauires acid conditions, the two types of waste streams must be kept segregated from each other.

The trivalent chromium so formed can be precipitated by treatment with lime.

Batch Treatment

A batch treatment system is generally applicable to flows of 200 gallons/hour or less although some treat up to 1,000 gallons/hour.

The oldest of treatment plants (and still in use) consists of a minimum of two tanks for each segregated waste stream, each tank of which is big enough to hold the effluent flow from one shift. The first tank is allowed to fill and then the flow is switched to the other tank and an operator adds the treatment chemicals. The tank is allowed to settle, the "clean" water on top is sewered and the sludge pumped out.

Sludge is held in tanks until removed to a disposal area. With the new regulations in effect for land disposal, disposal of this sludge is becoming more difficult. Other methods of treatment can reduce the magnitude of this problem and this is one other additional reason why this batch treatment method is less attractive than other more modern methods.

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Continuous Flow Treatment

Most systems installed today incorporate some continuous flow features. Figure VII shows a schematic layout of a typical waste treatment system for removing heavy metals, destroying cyanide and adjusting pH by almost completely continuous flow methods. These continuous flow systems require sophisticated instrumentation for measuring and controlling the treatment processes and this could be considered a disadvantage of these systems.

The final treatment stage shown in Figure VII has, in the past, commonly been a large settling tank or chamber. However, certain metal hydroxide sludges, produced by settling of fairly dilute suspensions of the metal hydroxide in water are gelatinous and will not compact into a dense sludge. With the new regulations for land disposal sites now in effect, these sludges are no longer suitable for land disposal and it has become almost a requirement for new treatment facilities to filter either the settled sludge or to filter the dilute slurry effluent from the pH-adjusting tank. Filtration not only produces a dry filter cake that can be land disposed but it also provides a treated wastewater of much higher quality than simple settling could produce and which can be recirculated in the rinse

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water or other water systems within the plant.

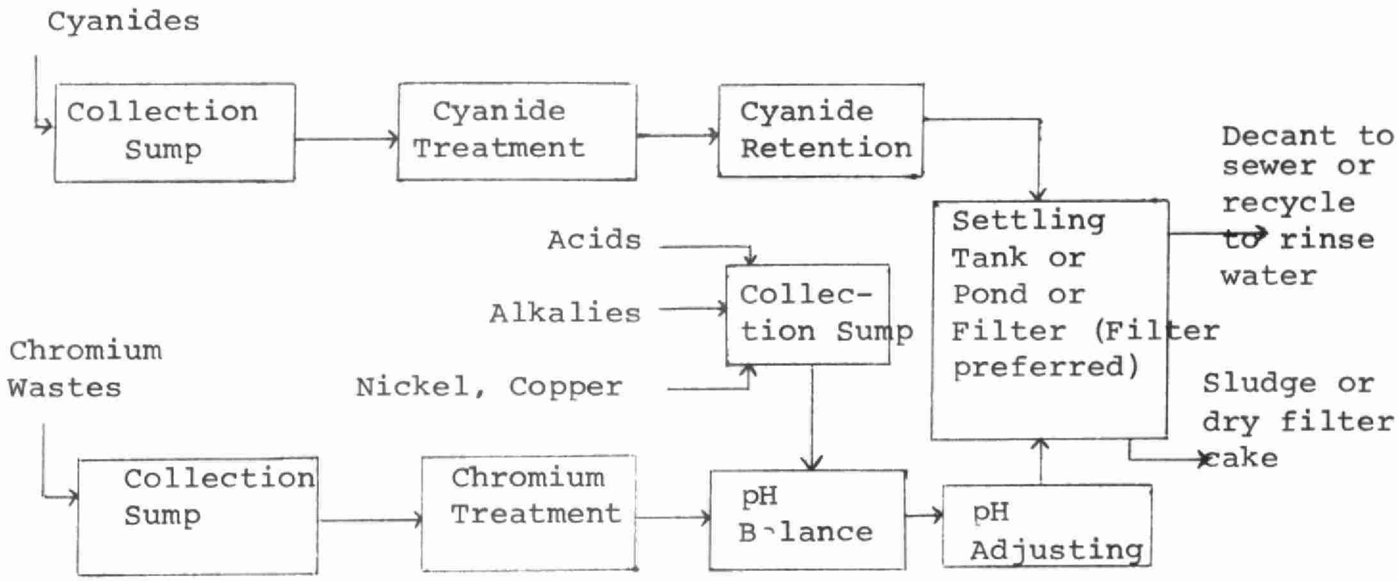

FIGURE VII
CONTINUOUS FLOW TREATMENT OF METAL PLATING WASTES

(C) Specific Treatment Systems

(a) Integrated Systems (Lancy System)

The integrated system incorporates treatment into the plating line itself. Parts coming from a plating bath enter a rinse containing an excess of the treating chemicals. Two tanks and two stages are used for chromium treatment, but in other treatments only one stage is used. The system is shown schematically in Figure VIII. The rinse bearing the contaminant and the excess treatment chemical constantly overflows into a large reservoir tank where the chemical reaction

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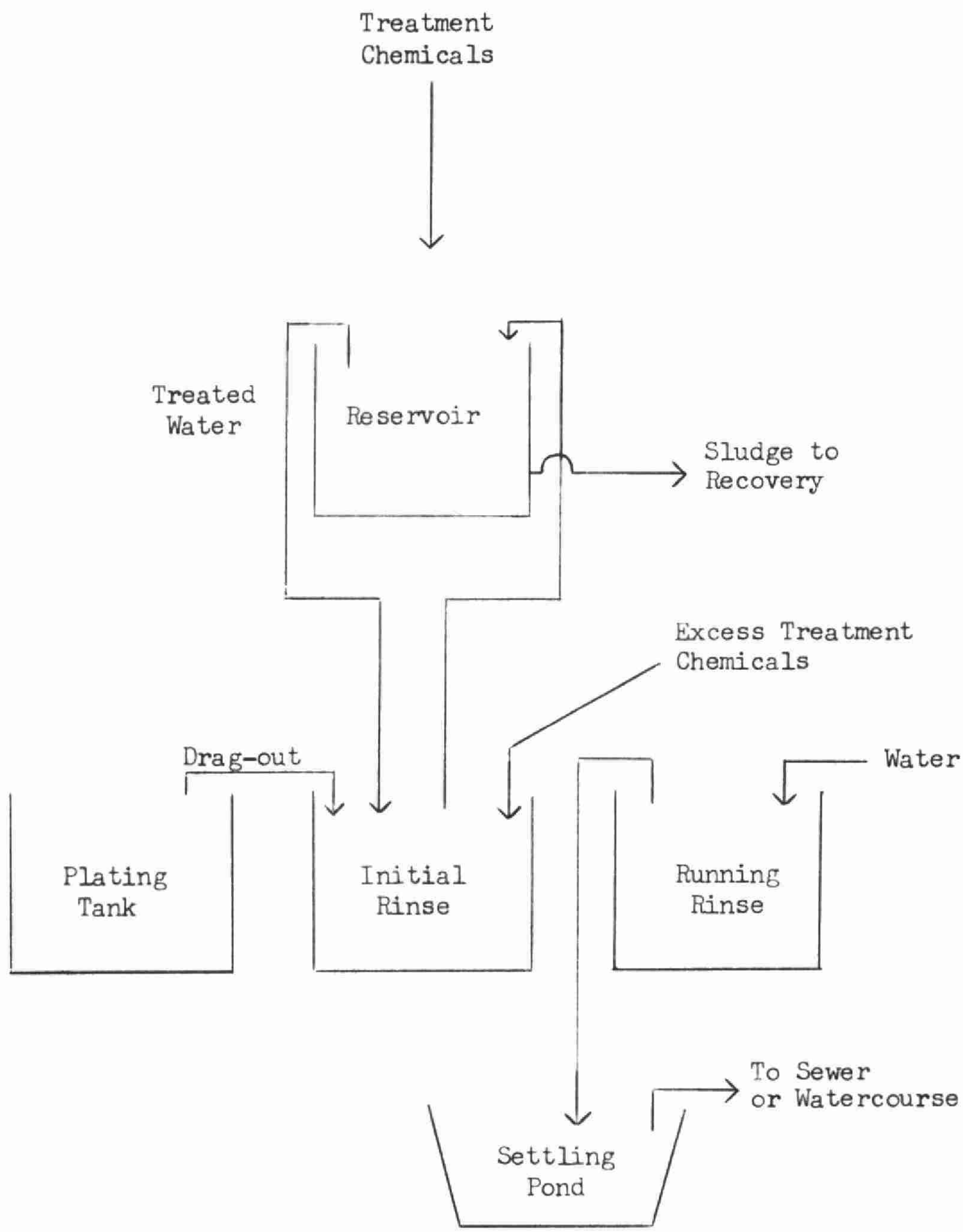
FIGURE VIII

INTEGRATED SYSTEM SHOWING RECYCLE



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has time to be completed and the precipitated metals have time to settle. Reactants are also added to the reservoir tank in an empirically determined quality. The work continues on into successive running rinses and any precipitated solids remaining in these running rinses are settled in a separate tank with the overflow going to the sewer. The treated wastewater is recycled from the reservoir back to the initial rinse tank containing the treatment chemicals.

In this system, the precipitated metals can be kept from each other in their own respective systems and the sludges are conditioned so that a high concentration, high density sludge of the particular metal oxide, hydroxide or carbonate is collected in the treatment reservoir. Recovery of valuable metals such as cadmium, nickel and copper is not only easy but is practised by all large users of this type of process. In some cases, this is sufficient to pay for the operating cost of the system.

Recovery is an obvious way of getting something back from an otherwise unprofitable waste treatment investment. Unfortuantely, recovery may be an expensive process in itself, or it may recover some undesirable or almost worthless material. In the plating industry,

recovery involves recirculating water and recovering plating chemicals. Present-day water and sewer cost increases are accelerating recovery approaches.

(b) <u>Ion Exchange</u>

The convention treatment for plating shop waste waters is oxidation of cyanides with a chlorine compound and precipitation of heavy metals with sodium or calcium hydroxide. This procedure is followed by separation of precipitated solids by one or a combination of clarifiers, settling lagoons, pressure filters or vacuum filters. The above procedures are capable of complete cyanide destruction and metal ion removal, however, the achievement of this requires:

(1) controlled efficient rinsing
(2) correctly designed and installed treatment equipment
(3) competent operator control
(4) sensitive and robust electronic control instrumentation
(5) first class mechanical and electrical maintenance
(6) accurate laboratory control
(7) spill collection systems and fail-safe equipment devices

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All the above requirements are seldom achieved together consistently mainly by default of Company management in recognizing the strict requirements for effluent ouality control.

The use of ion exchange techniques is a method which will simplify operating procedures and which will produce a more consistent effluent quality. Ion exchange systems can be used in two distinct ways in plating wastewater treatment.

(1) concentration of mixed dilute rinse waters by factors ranging from 100-200 to 1, thus enabling waste treatment to be completed on a batch basis. Batch treatment is easier to control than continuous treatment and does not require complex control instrumentation. Sludges generated from concentrated solutions are easier to dewater and exist in relatively small volumes.

(2) by segregating individual plating bath rinses, i.e., nickel, chromium, zinc, copper, etc., it is possible to return regenerated solutions from the ion exchange columns, after concentration, to the original plating baths.

Ion exchange systems can offer the following advantages in all or part in plating wastewater

treatment.

(1) metal recovery and re-use

(2) supply of de-ionized water

(3) lower capital and operating costs, and

(4) more reliable effluent quality control

Until fairly recently, ion exchange in plating waste treatment was not widely practised in North America and the first systems were used for recovery of nickel and chromium because of the high value of these metals. However, systems for mixed rinses including chromium, nickel, copper, zinc, and cyanide can be operated satisfactorily and the regenerant solutions can be treated batchwise for cyanide destruction and metal precipitation. Following is a description of one such system now in operation. The characteristics of the rinsing waste waters to be treated were:

	Average	Maximum	Minimum
Flow (IGPD)	41,000	53,000	33,000
Cu (ppm)	5		
Zn (ppm)	30		
CN (ppm)	20		
Ni (ppm)	1		

The mixed waste is passed through a series of three ion exchange columns:

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Unit #1 - cation resin in the sodium form to remove heavy metals (regenerated by sulphuric acid)

Unit #2 - highly basic anion resin in the hydroxyl form to remove all anions including cyanide (regenerated by sodium hydroxide)

Unit #3 - a second and identical bed of cation resin in the hydrogen form to remove sodium and deliver de-ionized water to a final storage tank. (resin becomes converted to the sodium form and will become #1 Unit in the next process cycle)

Wastewater from seven running rinse tanks flows into a common collection sump. The sump contains two pumps, each pump capable of handling the entire flow by itself.

The concentrated ion exchange resin regenerant solutions are treated by conventional methods to destroy cyanide, precipitate heavy metals and separate the sludge produced.

The de-ionized water is returned to the plating rinsing tanks. Figure IX is a flow diagram of an

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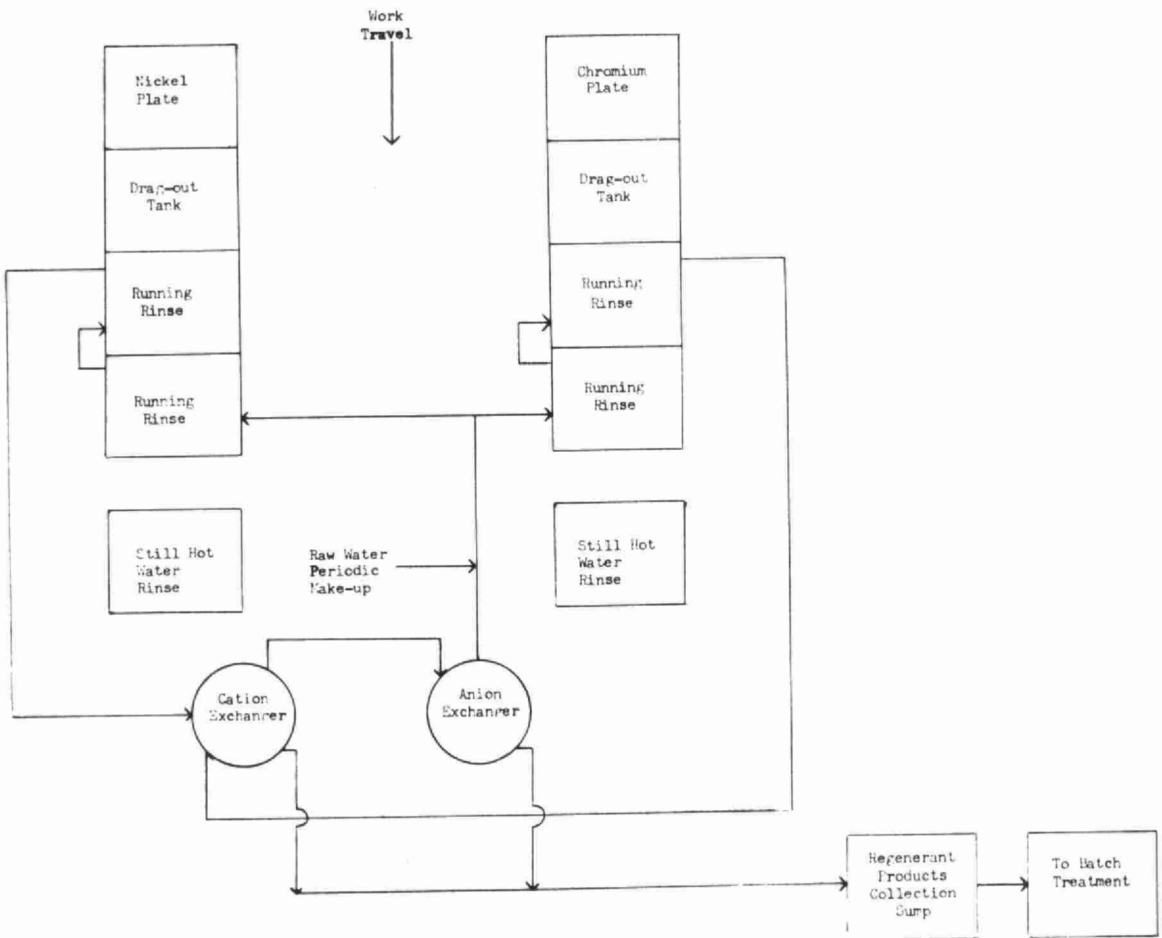
FIGURE IX

ION-EXCHANGE TREATMENT SYSTEM



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ion exchange nickel-chromium treatment system.

(c) Evaporative Recovery

Evaporation produces a pure distilled water and a solid residue consisting of the dissolved solids originally present in the water.

The principle of evaporative recovery of plating chemicals is an established technique. Figure X shows the most simple form in use in the plating industry.

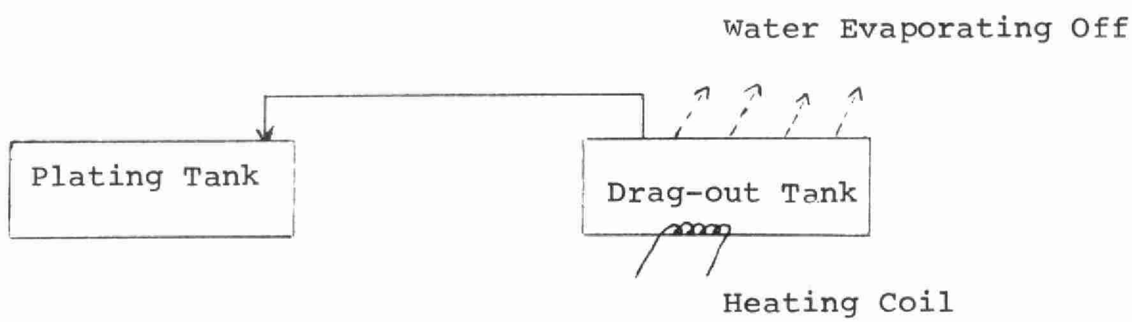

FIGURE X

The water in the drag-out tank is partially evaporated to the atmosphere to produce a more concentrated solution suitable for return as make-up to the plating tank.

Evaporative recovery is also a technique which can and is used for recycling rinse water and recovering

the plating solution. It is in use in Ontario and the technique will become more popular in the future not only in the plating industry but also in other industries generating wastes now considered economically untreatable.

Figure XI shows the bare essentials of a "closed loop" evaporative recovery system.

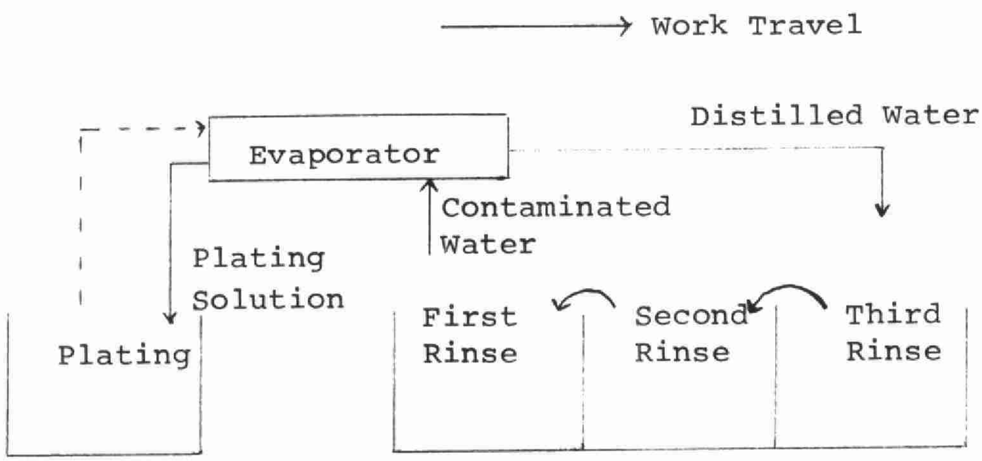

FIGURE XI

EVAPORATIVE RECOVERY AND RECYCLING

<u>Evaporative Recovery and Recycling</u>

Figure XII shows a more detailed description of the system. Overflow from #1 Rinse Tank (most concentrated) collects in a Holding Tank and is drawn by vacuum into the main body of the Evaporator. The solution is circulated through the shell side of the

Reboiler. Each pound of steam condensing in the tubes of the reboiler evaporates approximately one pound of water from the rinse solution.

A mixture of liquid rinse water and water vapour then re-enters the Evaporator and is again recirculated through the Reboiler. The water vapour, however, moves upward and passes into the shell side of the Condensor where cooling water condenses it as distilled water. The distilled water is transferred to the final Rinse Tank for recycle as clear rinse.

The liquid remaining in the Evaporator becomes a more concentrated cyanide solution with each pass through the Reboiler. When the desired plating strength is reached, it is valved over to the concentrate holding tank where it is available for make-up of the Plating Bath.

The capital cost of this systems appears competitive with other systems.

(d) <u>Reverse Osmosis</u>

Reverse Osmosis for the treatment of plating waste streams is now under development in Ontario, and at this time, appears to be feasible for nickel recovery.

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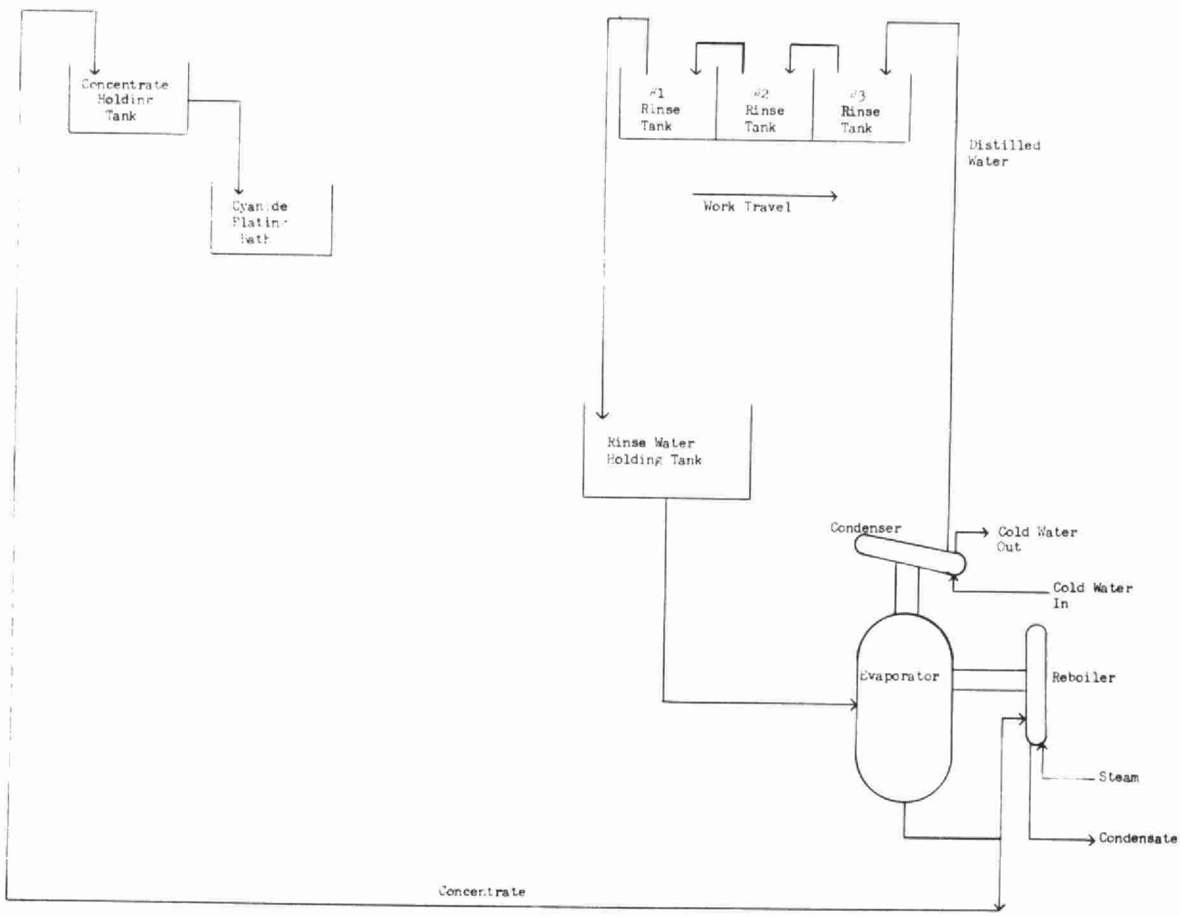
FIGURE XII

SINGLE EFFECT EVAPORATOR SYSTEM

FOR CYANIDE PLATING



The method has been given a field trial at a small plating shop. No change in plating quality occurred and nickel salt losses were practically eliminated. Calculated operating costs are much lower than the savings realized from the recycling of the nickel salt and pure water and the developer of the system is confident that reverse osmosis will play an important role in treating electroplating wastes.

(e) <u>Solids-Water Separation</u>

The solids formed in conventional batch treatment systems must first be dewatered before final disposal, usually at a landfill site. The disposal of sludges containing 4% solids and 96% water on land is no longer considered acceptable by the regulatory agencies.

Settling in large lagoons is being used but has generally proven unsatisfactory and unacceptable. The ultimate answer appears to rest in recovery and recycling processes producing no sludge or minimal amounts of sludge. However, before this ideal is fully reached, a satisfactory solution can be achieved through filtration, either vacuum filtration or pressure filtration.

<u>Special Surface Treatments</u>

The wastes originating from the variety of special surface treatments such as stripping of metallic coatings, anodizing, chromating, phosphating, painting

and paint stripping, depend on the operation being performed and the chemicals and metals involved. Almost invariably, in all of these operations, cleaning using alkaline solutions is performed prior to the primary operation and with the exception of painting, water rinses are used following the operation. These associated operations give rise to contaminated effluents containing the cleaning solutions and rinses in addition to periodic batch dumps of the primary treatment bath itself. In handling the wastes from these operations, all acids and alkalies must be neutralized, oils, greases and paint solids must be removed and the metals must be precipitated out of the solution before discharge to the sewer or watercourse.

Miscellaneous

Based on experience in observing plating waste treatment procedures over the years, there are a number of points which bear repeating.

(a) Toxicity of Metal Finishing Solutions

Because of the very high strength and toxicity of many of the chemical solutions used in the metal finishing industry, it is extremely important to ensure that batch or slug discharges of these materials to a watercourse or biological sewage treatment plant do not occur. There are many cases in our files where a discharge of a relatively small volume of a toxic solution has wiped out the fish life of a relatively large

stream such as the Nith River of the Grand River. The biological floc of a municipal sewage treatment plant can be completely destroyed by sudden discharges of toxic materials to the plant. This is particularly true in the smaller municipalities. It is now required that pumps and other critical pieces of treatment equipment be duplicated and available as stand-by facilities for emergency use as required. The use of emergency holding tanks or large emergency impoundment basins, if land is available, is strongly recommended. Valve failures, pipe connection leaks and cracks in concrete trenches are common and must be guarded against by protective curbing and by specially designed sewer systems and drainage patterns so that toxic chemicals cannot gain access to the normal wastewater or storm water outlets. A treatment system using gravity to direct the flows is preferred to one requiring pumping. Automatic pH analysers connected to alarm systems are essential to a good waste control programme. Closely related to these measures is a training programme for plant employees regarding the proper use of manufacturing equipment and plant drains and emphasizing the necessity to quickly stop spills of any sort if and when they do occur. Such a training programme is an essential part of any good waste control programme.

Frequent unexpected visits by municipal inspectors to industries on the municipal systems will encourage the plant to minimize the potential for spills.

(b) Monitoring of Waste Effluents

Every industry should be required to monitor the quality of its waste effluent in a similar fashion as it would monitor the quality of its product. If such a monitoring programme is in effect, the industry has an incentive to maintain or improve the waste effluent quality.

In this connection, the use of certain simple paper tests for cyanide and the heavy metals is not recommended for effluent monitoring purposes. Time and again, it has been found that misleading results have been produced and, in fact, fish kills due to cyanide have occurred while the plant effluent was being monitored by one of the paper tests and giving results showing the absence of cyanide. In one particular case, the paper used was simply not sufficiently sensitive to the low concentration having the ability to kill fish. It must be remembered that a plater thinks in terms of percent solutions in his production facilities and it is difficult for him to think in terms of parts per million. A 1% solution (which is a weak solution to a plater) contains 10,000 ppm. 0.1 ppm cyanide will kill fish.

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PULP AND PAPER

In general, the surveillance and pollution control enforcement work for the pulp and paper industry in Canada remains the responsibility of the respective provincial pollution control agency or the federal government. There are, however, certain pulp and paper making operations located in larger municipalities that are able to discharge process wastes into the municipal sewerage systems and thereby provide easy solutions to potential pollution problems. In Ontario, there are thirteen such operations located in Metropolitan Toronto, Georgetown, Brantford, Brampton and North Bay. Monitoring and surveillance of the process wastes from these plants is left to the municipality and the Province only becomes involved upon request.

Those pulp and paper making operations discharging wastes to municipal sewerage systems tend to be small in size and do not generally include chemical pulping operations. The products include a whole range of fine and coated papers, tissues and paperboards. Raw materials are purchased pulps, waste paper for recycling, raw paper and raw paperboard. In the U.S. and Europe there are a number of instances where treatment plants have been built to treat jointly pulp mill effluent and municipal wastes. Waste loadings from the mill often

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represent more than 80% of the total loading so that the municipality is really taking over the industrial waste problem. There are, however, capital and operating cost benefits for the municipality to offset this. Because the number of these plants is small, the following discussion will exclude pulping wastes and will deal with situations where the paper mill effluent represents a much smaller proportion of the waste loadings to the treatment plant.

General

For the purpose of enforcing sewer-use by-laws or negotiating the inclusion of a paper mill's wastes in a municipal sewerage system it would be highly beneficial to have knowledge of the sources and characteristics of the waste streams associated with the various processes. This is the prime purpose of this presentation.

The manufacturing operations of paper or board can be conveniently broken down into two processing areas that give rise to liquid wastes:

(a) Stock preparation
(b) Sheet forming and drying.

In addition, there are "converting" operations including

coating, embossing, impregnating, saturating and forming of special shapes and sizes, which can give rise to liquid wastes. Of these, "coating" is the only one that will be discussed.

Chemical preparation areas also exist in all mills and can be sources of heavy waste loadings. The types of chemicals used include fillers for paper, alum for pH control, sizes, resins, glues, starches, dyes, pigments, various acids and alkalis and certain organic chemicals such as formaldehyde which are used as solvents and polymerization agents.

(1) Chemical Preparation

The chemicals used in paper making operations are normally received in drums or bags and are made into stock solutions on a batch basis. Some chemicals, (e.g. caustic soda and liquid alum) are received in bulk and used directly from storage.

Preparation of stock solutions is most often accomplished in batch mixers which may range from 200 to 1,000 gallon capacity. These solutions may be used directly from the mixer or may be pumped to intermediate storage tanks.

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Wastes from the chemical preparation area are normally small in quantity because chemicals cost money. It is not uncommon, however, to encounter leakages and spills which find their way into the sewer system, but the bulk of the liquid wastes in this area originate from washing-up of equipment. During the course of a day, the batch mixing equipment may be used to prepare a variety of different chemical solutions, dyes, filler solutions, etc., and wash-ups are required between changes. Occasionally, it may be necessary to dump an amount of the stock solution because it is not required, and this will give rise to a surge of wastes.

Because of the variety of materials used, it is not possible to indicate any general waste characteristics associated with the chemical preparation area. Suspended solids, pH and colour are the most common parameters to test for, although BOD_5 could be significant from certain types of chemicals.

(2) <u>Stock Preparation</u>

As the name implies, the stock preparation area of a mill is that area where the pulp or fibre is prepared prior to being formed into a sheet on the paper machine. A variety of operations may be encountered in the stock

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preparation area, largely dependant on the source and type of fibre being used.

If virgin chemical or groundwood pulps are used, the processes are relatively simple. The pulps are slurried by severe agitation in a suitable vessel, may undergo some conditioning (beating), may be cleaned by screens or centrifugal cleaners and are then sent to storage either as high density or low density pulps. The final step is dilution of the pulp slurry to the consistency required in the paper-making operations.

Where recycled fibres are being used, the processing is more complex and may include some or all of the following stages:

(a) Pulping or defibering
(b) Cleaning and screening
(c) Washing to remove contaminants
(d) Dewatering or thickening
(e) Bleaching
(f) Bleach washing followed by thickening

Step 'C' may involve de-inking if printed materials form part of the raw fibre supply.

The waste volumes and flows associated with the

stock preparation processes will vary from mill to mill. There will be the normal process wastes which themselves will vary considerably, (as shown in Table A) and there will be wastes generated as a result of spills and equipment wash-ups.

TABLE A

Characteristics of Wastes from Stock Preparation Area

Flow gals./ton product	Suspended Solids lbs./ton of product	BOD_5 lb/ton product
5,000 - 30,000	50 - 600	20 - 150

(3) Papermaking Operations - Sheet Forming & Drying

Two types of equipment are used today to convert a dilute suspension of fibres into a sheet of paper or board; the Cylinder Machine and the Fourdrinier.

In the cylinder machine, (Fig I) a wire-covered cylinder is mounted in a vat to which the fibre slurry

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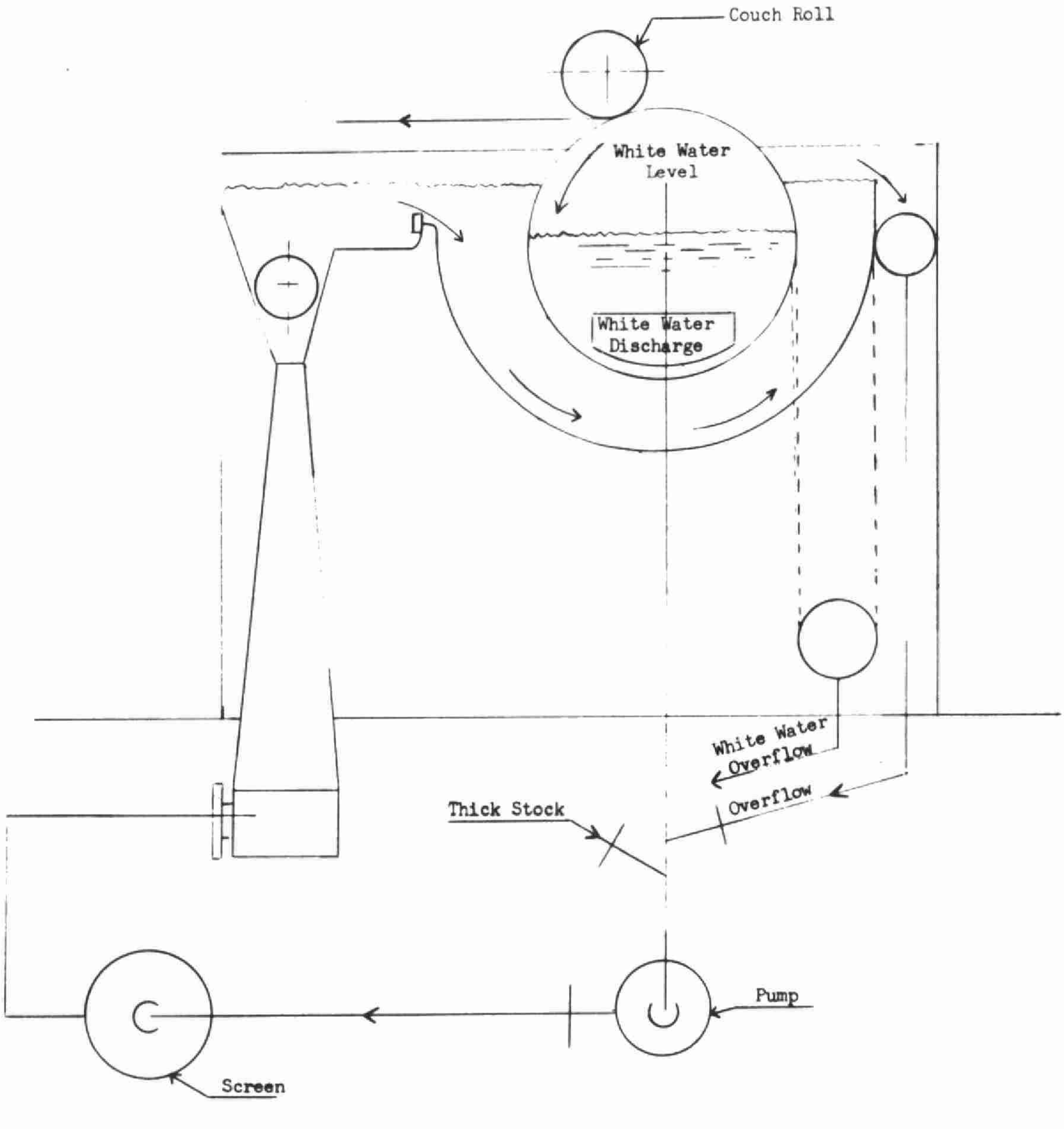
FIGURE I

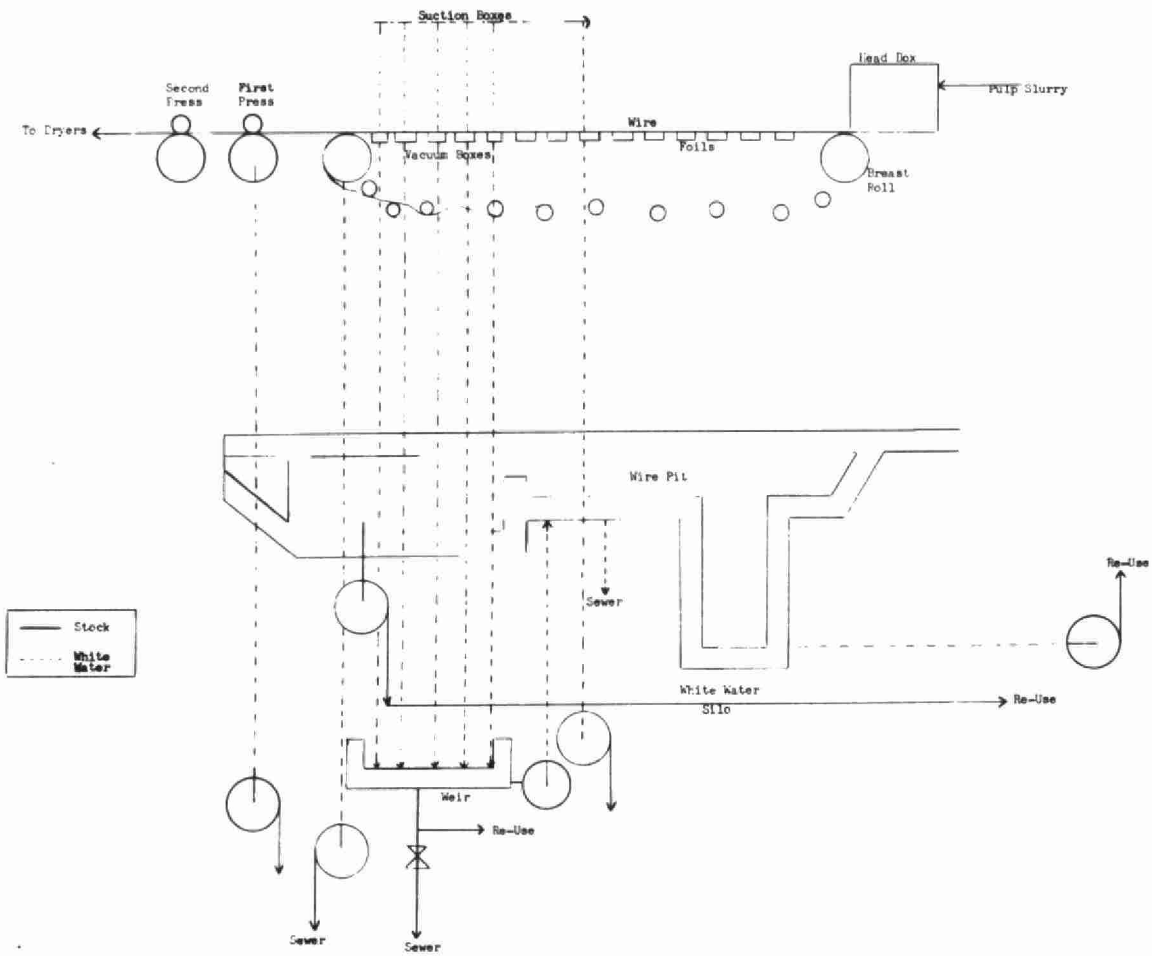
CYLINDER MACHINE



is introduced. As the cylinder is revolved, water drains inwardly through the screen and the sheet is formed on the outside. The wet sheet is removed at the top of the cylinder, passed through press rolls, and then sent to steam-heated, cylindrical drying drums where the final paper sheet is produced.

In the Fourdrinier, (Fig II) fibre slurry is introduced at one end of a continuously moving, horizontal wire screen by means of a head-box.

FIGURE II
FOURDRINIER



As the slurry moves along with the wire it progressively loses water, this process being enhanced by special devices placed under the wire, and the wet sheet is formed. The wet sheet then passes through press rolls and dryers as in the case of the cylinder machine.

For both cylinder and Fourdrinier machines, the water that drains from the fiber slurry is known as white-water or machine white-water. The name is often a misnomer as "white-water" can be almost any colour.

Where practical, white-water is re-used in the stock preparation areas. Excess white water is discharged to sewer and represents a major waste source. It is also necessary to clean the felts and wires of these machines continuously and this is accomplished by high pressure sprays using fresh water. This shower water is normally sewered and can contain high levels of suspended solids.

White-waters contain large amounts of suspended solids, both fibre and inorganic fillers, can exert substantial BOD_5's if large amounts of organic additives (starch, resin, etc.) are added and may be highly

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coloured due to dyestuffs. Table B presents some characteristic data for white-waters:

TABLE B

Characteristic Data for Machine White Waters

Flow Gallons/ton of paper	Suspended Solids lbs./ton paper	BOD_5 lbs./ton paper
2,000 - 60,000	5 - 400	3 - 100

Concentrations of suspended solids will lie in the range of 300 - 6000 mg/l, with the lower values originating from the manufacture of simple, unfilled papers and boards and the higher values pertaining to bond and book paper manufacture.

Other sources of wastes in this area will include leakage and spillage, head-box dumps and washing-up wastes. Waste loadings from wash-ups in mills making a number of different grades of product or mills on 5 or 6 day operation can be high.

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"Broke" is the name given to scrap paper or board that results from a break on the machine. In most mills this material is re-used but in some cases it cannot be conveniently re-used. Disposal is then conducted either in the dry state by hauling the material to a nearby dump or incinerator, or in the liquid state by slurrying-up the broke and discharging the resultant slurry to sewer. This practice is not too common but can produce a substantial waste loading.

(4) Coating

Coating operations involve the application of a composition of pigments, adhesives and other additives to one or both sides of a roll of paper. Coatings are applied to mask or change the appearance of the base stock, improve capacity, impart a smooth and receptive surface for printing, and to provide special properties for particular purposes.

Coatings can be applied either on-line to the papers coming out of the dryer section or, more commonly, in a separate, independent operation. Some mills conduct coating operations only, receiving the base paper in large rolls from paper mills.

The coatings are applied to the base paper in the

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form of a water suspension or "coating colour". The total solids content (pigment plus adhesive, etc.) will vary from 35 - 70 percent. The coating colour is applied to the paper usually by roll, with excess material being scraped off by a trailing blade or blown off by an 'air doctor'. The excess material is collected and recycled such that there are no direct wastes from the application area other than leakage, etc. Where a coating operation is independant of a paper making operation, it will have its own chemical preparation area generating wastes similar to those already discussed.

The main source of wastes from the coating operations is washing-up. Each time a different grade of coated paper is made it is necessary to wash down the coating applicator equipment. In some cases, this is done on a daily basis as a matter of routine to prevent build-up on equipment. The frequency of wash-ups, their duration and the characteristics of the wastes generated should be determined if the wastes are to be discharged to a municipal sewerage system.

Requirements for Discharge to Municipal Sewerage System

As we have seen, there are basically three waste

parameters that may be of concern if discharge to a municipal sewerage system is being considered - suspended solids, BOD_5, and colour. The acceptability of the wastes into the sewerage system will depend on there being adequate sewage treatment facilities associated with the system and the limits imposed on any discharges by sewer-use by-laws.

Where secondary treatment facilities exist, colour does not usually present a problem as most dyes are readily oxidized. However, bear in mind that a highly coloured effluent from a municipal sewage treatment plant could lead to public criticism of the Municipality and it is worthwhile to check on the types of dyestuffs being used and determine whether they are "refractory."

Most mill waste waters will exceed the prescribed limits on suspended solids for discharge to the sewers. Thus, some kind of pretreatment is often necessary. In certain cases agreements can be reached wherein the municipality agrees to accept a suspended solids loading in excess of the prescribed loading upon payment of a sewer use surcharge. It should also be mentioned that wastes volumes may be excessive and require reduction before being acceptable to the municipality.

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BOD_5 is rarely a problem in the cases considered here except for mills operating de-inking processes. At the present time there is only one such mill in Canada although more may come into existence with the public demand for more recycling of waste paper.

<u>Waste Volume Minimization</u>

Most papermaking operations employ maximum re-use of machine white-waters to effect savings on water, heat, and to minimize the losses of chemicals and fibre. However, it is still possible to encounter operations where the water usage, and hence the waste discharges, are far greater than necessary and in such cases, the companies should be urged to implement a major water conservation program.

Better planning of product grade manufacturing can also result in much reduced waste loadings. For example, if colour grades of paper are being made, it is often possible to schedule the lighter colours ahead of the darker colours and thereby allow excess stock and white water to be used in the manufacture of the next grade.

One very common source of waste waters in mills is fresh water hoses left running continuously. This is

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usually done because it is expedient for the operators to have fresh water on hand, or it may be a question of poor maintenance with no way to shut-off the flow. Self-closing nozzles are now available to solve problems of this kind.

An inspection of the processing facilities should quickly reveal areas where excess water is being used. Simple questioning of company personnel should determine whether a particular water stream is necessary and whether it can be reduced or eliminated. It often requires people from outside to point out to mill personnel that excessive, unnecessary water is being used.

Pretreatment of Mill Waste Waters

Even where water conservation programs are in effect it is unlikely that the waste waters from most paper making operations will comply with sewer-use by-law requirements, particularly for suspended solids. In some cases, special concessions might be made so that the wastes can be treated in the municipal sewerage system upon payment of a surcharge. The immediate question raised by the companies in these cases is whether it is more economical to pay the surcharge (which will be a continuing payment with no tax concessions) or to install

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pretreatment facilities where depreciation and other tax concessions might apply. For other mills, pretreatment will be necessary to reduce waste loadings to acceptable levels.

(1) Suspended Solids

A number of processes are in common use throughout the paper-making industry to reduce suspended solids in mill waste waters, with some being favored more highly than others. In mill jargon, the equipment installed to perform this task is known as a 'save-all'.

(a) Screening

The use of screens to separate fibrous materials from water is well established in the industry. However, one of the drawbacks is that the use of screening to remove very fine particles is not normally reliable due to excessive operating and maintenance costs. Very fine screens are highly susceptible to plugging and require almost continual back-washing or changing.

A variety of screens are in use ranging from the simple gravity sidehill screen, through the vibrating and rotary screens to the newer parabolic, D.S.M. type of screen.

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(b) Flotation

Dissolved air flotation is a very efficient method to recover fibre from waste waters. The process, however, requires constant feed conditions if it is to perform well and tends to be highly susceptible to upsets. Units such as the 'Sveen Pederson' and the 'Krofta' flotation save-alls are quite common to the industry.

Recently, resin polymers have become available that have the ability to readily 'float' suspended materials. The cost of these materials is decreasing and their high efficiency if used with a dissolved air flotation unit is making an economically attractive alternative for the industry.

(c) Filtration

Both gravity and vacuum filtration processes are commonly employed to reduce suspended solids. In most cases, the filter units are simple, sometimes using pulp fibre as a 'sweetening stock' to form a filter mat. Where large amounts of very fine particles have to be removed it may be necessary to employ precoat filters. These units are not too common because of high operating costs and the resulting sludge disposal problems.

Vacuum disc filters, vacuum rotary filters, and the

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simple gravity rotary filters are most commonly used.

(d) <u>Sedimentation</u>

The use of the gravity clarifier to remove suspended solids from liquid wastes is well established in the waste treatment field. Most applications are in the area of external waste treatment facilities but there is no reason why clarification cannot be used as a pretreatment system. Dewatering and disposal of accumulated solids sludges will be an important consideration in a decision to install a clarifier but cost will probably be the most important factor.

Sedimentation lagoons or settling ponds are a useful alternative, providing land is available. One drawback with these ponds is the cost of dredging or cleaning out the accumulated solids. This is necessary if good efficiency of solids removal is to be maintained. Perhaps the worst feature about ponds of this type is the generation of odours during warm weather. These odours can be particularly obnoxious and are due to excessive anaerobic biological activity taking place. For this reason, the use of these ponds in a built-up area should be discouraged.

The selection of the type of process to be employed

to reduce suspended solids will depend on the degree of removal required, the capital and operating costs, any attendant problems such as sludge disposal and the general economics of pretreatment versus surcharge.

(2) BOD_5

Where pretreatment to reduce BOD_5 is required, any of the conventional biological oxidation systems or chemical treatment can be employed. The requirement to pretreat for BOD_5 reduction is rare but it could increase if more waste paper recycling plants are built.

(3) Colour

It is highly unlikely that a colour problem will exist if secondary treatment is employed in the municipal sewerage system. In the case of the small town and large paper mill jointly treating wastes, colour could persist through the system and create an unacceptable aesthetic pollution problem. Most colours originating from dyes can be broken down by oxidation (chlorination) but certain persistent dyes may require specialized chemical treatment before they can be eliminated. If the colour is associated with a pigment in the colloidal or semi-colloidal state, chemical conditioning may be necessary before the offending materials can be settled-out or

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filtered from the effluent.

(4) <u>Other **Waste** Paramaters</u>

There may be other components in the waste effluents from a paper mill that could be detrimental to the operation of the municipal sewerage system. An awareness of the operations being carried on in the mill together with a detailed list of all chemicals used in the processing should provide ample clues as to whether other parameters might create problems. Heavy metal ions, present in large enough quantities, could be toxic to the bacteria in a biological treatment system. Excesses of pH could create problems in the sedimentation processes and the biological treatment units and excesses of phenolic-type materials could pass through a municipal treatment plant without much reduction and cause subsequent water quality problems in the receiving watercourse.

With a good working knowledge of the mill processing and chemical usage, and an awareness of the types of problem that can arise and their source, the municipal official should be able to decide with a reasonable degree of confidence whether or not mill wastes are acceptable for discharge into the sewerage system. Arbitrary

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decisions without the backing of a through investigation should be discouraged as they could lead to overwhelming problems in the future or preclude the mill from adopting a solution which is mutually beneficial to both mill and municipality.

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READY MIX CONCRETE

In the Metropolitan Toronto area there are approximately forty ready mix batch plants where concrete is manufactured by mixing various percentages of aggregate, cement and water. Aggregate can take the form of coarse stone, fine stone or sand, depending on the end use of the product. The aggregate is kept in stock piles and the cement is stored in a silo and on occasion, chemicals of various types are added to make specific kinds of concrete.

In late 1971, staff of the Industrial Wastes Branch met with representatives of the Ready Mix Concrete Association of Ontario. It was pointed out to the members that the practice of disposing of truck washout wastes into rudimentary settling tanks that overflow to adjacent watercourses could no longer be tolerated. It has been the practice of all ready mix companies that when a ready mix truck returns to the plant at the end of the day or in some cases when a change in grade of concrete is to be carried in the barrel mid-way during the shift, the driver disposes of the returned concrete in an isolated location on the plant property and then proceeds to fill the barrel on the truck with 200 to 300 gallons of water. The barrel is left turning and the contaminated water is then discharged into the settling

tank. Lab analysis of this discharge has revealed that it is highly alkaline, having a pH in the range of 12.5 to 13.5, and having a high suspended solids concentration of 100 to 300 parts per million. As the Province's guidelines are a pH of lower than 9.5 and a suspended solids concentration of less than 15 parts per million, it became evident that these wastes could not continue to be discharged by the company in the haphazard manner previously described.

In an attempt to assist the ready mix concrete industry, the problem was given to the Ministry's Research Branch who came up with several alternative methods for treating the wastes prior to discharge to a watercourse. These included the addition of sulphuric acid, carbon dioxide, sodium bicarbonate, waste smoke-stack gas and natural gas to the wastes in an effort to neutralize the alkali.

The first of these methods, the use of sulphuric acid, was found to be unacceptable since the attainment of an endpoint in the range 5.5 to 9.5 was an extremely difficult matter. The addition of a few drops of acid as the endpoint was approached resulted in a rapid sharp drop in the pH value. This method could only work with the use of experienced personnel and a special meter with a probe

that would not become contaminated. It is very easy to overshoot the required endpoint. This method costs about $10.00 per 1,000 gallons treated and is in use at several plants. The other four methods attempted proved even less acceptable than the use of sulphuric acid. Two other methods were considered, spray irrigation and trucking to a disposal site. However, the former would require the availability of suitable soil and extremely careful spray control while the latter was too expensive even to consider.

One additional method, that of reuse of the contaminated wash water, then appeared to be the most acceptable method to use. With the reuse method, wastes are discharged from the truck into the first of a series of settling tanks where the suspended material settles and the clarified liquid overflows into the adjacent tank. An optimum settling time has been determined and this is used when calculating the size of the settling facility. The clarified effluent is directed into a holding tank where it is pumped back to the truck wash-rack to be used to rinse out the next truck.

Another adaptation of this method of treatment has been put into use by several companies in the Metro

Toronto area who have purchased automated machines similar to the Jadair "Redi-Wash". The trucks are filled with reuse water, backed up to the machine and the liquid is dumped into the tank. The machine is equipped with scrapers which continuously remove the cement fines while the settled aggregate is removed at a different location on the machine. One company has been successful in reclassifying this aggregate into its components and stockpiling the material for further use in various grades of concrete.

Winter operation of the "reuse" treatment method (both automated and the simpler settling tanks and return pumps) requires some method of heating to ensure that piping and controls do not freeze. Some companies have erected buildings to house their equipment and one company piles heated sand against one wall which provides ample heat.

Since our initial contact with the Ready Mix Association of Ontario in mid-1971 and subsequent contact with the individual companies in early 1972, of thirty plants that formerly discharged contaminated wastes (pH 12, S.S. 200-300 ppm) into various creeks and rivers in

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the Metro area, fourteen have installed or have an order automated mechanical reclaim equipment (at an approximate cost of $50,000.00 each), five have installed other methods for the total reuse of liquid wastes, seven have started or are about to start construction of reuse facilities and only four remain as before.

In summary, therefore, water pollution by the Ready Mix Concrete industry is a matter of improper disposal of truck washing wastes. However, this problem may be overcome either by neutralization and settling of the washwater or by settling and re-use of the washwater. The latter is preferred since problems of pH control associated with the former are obviated. In addition, the re-use system can provide aggregate which after classification may be re-cycled back into the product.

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WATER TREATMENT AND CONDITIONING

Water treatment and conditioning operations may be classified as follows:

1. Boiler feed water treatment
2. Cooling water treatment
3. Process feed water treatment
4. Wastewater treatment.

All of these operations require the use of chemicals and all give rise to wastewater discharges containing these chemicals.

Boiler feed waters are chemically treated to prevent corrosion, to minimize scale build-up and to optimize the use of the feed water for the production of steam. In high pressure systems for power generation this usually involves complete demineralization by ion exchange.

Chemical treatments are applied to cooling water systems (most commonly the recirculating type of system) to prevent corrosion, to minimize scale build-up and deposition of entrained suspended solids, and to prevent the growth of bacterial and fungal slimes and the consequent attack and decay of cooling tower materials.

Process feed water treatment depends upon the feed

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water quality requirements. This may range from simple screening to alum flocculation, colour removal and/or ion exchange demineralization.

Wastewater chemical treatments are commonly associated with specific pollution and/or aesthetic problems. This may involve coagulant aids for suspended solids removal, foam control, odour control and the control of slime growth.

GENERAL CHARACTERISTICS OF CHEMICALS USED IN WATER TREATMENT AND CONDITIONING

Boiler Treatments

Boiler feed water treatments fall into two general categories, external treatments and internal treatments. The nature of the treatments and the types of chemicals employed are as follows:

External Treatments

	Treatment	Chemical Employed
(1)	Hot Process Softening	Lime, soda ash, coagulant aids, (polyelectrolytes)
(2)	Cold Process Softening	Alum, lime, coagulant aids
(3)	Ion-Exchange	
	(a) Softening	Regenerants: NaCl, H_2SO_4 HCl, $NaHSO_2$

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	(b) Demineralization	Regenerants: HCl, H_2SO_4 NaOH
	(c) Dealkalizing	Regenerants: NaOH, H_2SO_4 NaCl, HCl
	<u>Internal Treatments</u>	
(1)	Softening	NA_2CO_3, Na_3PO_4, NA_2HPO_4, NaH_2PO_4, $NaPO_3$, NaOH, EDTA, NTA
(2)	Dissolved Oxygen Removal	NA_2SO_3, Hydrazine
(3)	Dispersents or Sludge Conditioners	Na Lignosulfonates, Tannins, Polyacrylates, Polyacrylamides, Acrylonitriles, Na_2SiO_3
(4)	Corrosion Control	Morpholine, Cyclohexylamine Octadecyl-amine, N.N-diethylethanolamine,

Other boiler treatment chemicals include clean-out compounds and descalers such as citric acid and sulfamic acid as well as boil-out compounds which are essentially alkaline phosphate solutions with traces of chromate.

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Cooling Water Treatments

Cooling water treatments fall into three general categories, corrosion controls, scale inhibitors and biological growth controls.

Corrosion Control	$NaPO_3$, Na_2HPO_4, $Na_2Cr_2O_7$
	Modified Lignins Tannins, Organo Phosphorus Compounds, Zinc Compounds.
Scale Control	Phosphates and Sequesterents such as EDTA and NTA
Biological Growth Control	
Chlorine Chemicals	Na or Ca Hypochlorite, Chlorine, Stabilized Chlorine Dioxide.
Chloro-Phenols	Na Pentachlorophenate, trichlorophenate, etc.
Organo Sulphur	Na Dimethyldithio Carbamate Mercaptobenzo Thiazoles
Bromo-Ketones	2 - Bromo - 4 - Hydroxy Acetophenone: Bis 1.4 Bromoacetoxy - 2 - butene
Amines & Quaternery Ammonium Compounds:	Benzyl Ammonium Chloride Coco amines
Broad Spectrum	Na-methylene-bis-isothiocyanate

Water and Waste Treatment Chemicals

Water and waste treatment chemicals have wide

application in industry. Some of these chemicals and applications have already been discussed in the sections dealing with boiler and cooling water treatments.

The following are the categories of uses in the water and waste treatment field and the chemicals associated with these uses:

(1) <u>Flocculants and Coagulants</u>

- (i) Alum
- (ii) Polyelectrolytes
  - (a) Polyacrylamides
  - (b) Sulphonated aromatics
  - (c) Polyacrylimides
  - (d) Polyglycols
  - (e) Naturally-derived polymers

(2) <u>Corrosion Inhibitors</u>

- (i) Phosphates (Zinc)
- (ii) Chromates (non potable water systems)

(3) <u>Chemical Oxidants and Bacteriocides</u>

- (i) Chlorine
- (ii) Hypochlorite
- (iii) Chlorine Dioxide
- (iv) Ozone

(4) Sequesterents - Chelating Agents (Non-potable water systems)

(i) E.D.T.A. (Ethylene Diamine Tetraacetic Acid)

(ii) N.T.A. (Nitrilo Triacetic Acid)

(iii) Phosphates

(5) Scale Inhibitors (Non-potable Water systems)

(i) E.D.T.A.

(ii) Acids

(iii) Phosphates

(iv) N.T.A.

(6) Defoamers (Waste Treatment Predominantly)

(i) Petroleum distillates (Kerosene)

(ii) Long Chain fatty alcohols

(iii) Paraffin oils

(iv) Silicone hydrocarbons

(v) Esters (Polyglycol esters, ethoxyglycerides, etc.)

(7) Demulsifiers (Waste treatment systems)

(i) Inorganic salts (ferric chloride, calcium chloride)

(ii) Acids

(iii) Polyelectrolytes

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(8) Ion-exchange Systems, Regenerants

See under boiler water treatments

(9) Acids and Alkalies -

Usually inorganic. Such as H_2SO_4, NaOH, Na_2CO_3

(10) Odour Control Agents

(i) Chloro benzenes

(ii) Perfumed oils

(iii) Esters

WASTE DISCHARGES ARISING FROM WATER TREATMENT AND CONDITIONING

As mentioned previously, all of the water treatment and conditioning processes discussed give rise to some form of wastewater discharge with a consequent loss of chemicals used in the processes.

Blow-downs from boiler systems using internal treatments may be as high as 10% of feed water requirements with less blow-down for the high capacity plants. Typical boiler water conditions are in the following ranges:

Total alkalinity as $CaCO_3$ .... 325 - 500 ppm

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Caustic alkalinity	....	180 - 350 ppm
Phosphate	....	10 - 40 ppm
Total Dissolved Solids	....	1,400 - 2,800 ppm
Suspended Solids	....	Trace - 400 ppm
Chelates (EDTA, NTA, etc.)	....	10% to 15% above stoichiometric requirement

These typical conditions would closely parallel the characteristics of the blow-down from such systems.

The characteristics of wastewater discharges from boiler treatments utilizing external processes such as suspended solids removal, softening and demineralization are less well defined. Suspended solids removal processes involving alum and polyectrolyte flocculation give rise to clarifier sludge discharges containing suspended solids and precipitated iron. Softening processes may produce high chloride backwashes and/or precipitated calcium salts. Demineralization processes involving ion exchange give rise to highly acidic and highly alkaline waste discharges from the regeneration of ion exchange columns.

Generally, blow-down from boilers utilizing internal treatments present no problems when discharged to municipal

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sanitary sewers. The discharge of these wastes to storm sewers and surface waters should be discouraged.

Clarifier sludges, demineralizer regenerants and softener backwashes constitute concentrated liquid wastes and should be handled accordingly. Acidic and alkaline rinse waters from demineralizer regeneration can be mixed to provide a degree of neutralization and under controlled circumstances can be discharged to storm or sanitary sewers.

Of the three categories of cooling system treatment chemicals, biocides and corrosion inhibitors are most significant in terms of potential environmental effects.

Corrosion control is commonly achieved by the production of a corrosion resistant coating on the metal surfaces via the use of chromates, phosphates, zinc salts, tannins and lignins in a variety of formulations. Tannins, lignins and polymeric compounds are also incorporated into corrosion inhibitor formulations as dispersants for suspended matter picked up from the air in open recirculating cooling water systems.

Of principal concern in these formulations are the

metals chromium and zinc. Both chromium and zinc exhibit acute toxicities to fish and other aquatic life and zinc is also implicated in sublethal effects which adversely affect fish reproduction.

Current Ministry of the Environment effluent objectives for these metals in discharges to natural waters are 1 ppm maximum. Municipal sanitary sewer-use regulations generally specify maximum permissible concentrations in the 3 to 10 ppm range.

Operating concentrations for chromate in open recirculating cooling systems are in the range of 15 to 80 ppm. Operating concentrations for zinc may be 2 to 15 ppm as zinc sulphate in the phosphate/chromate/zinc formulations and 10 to 20 ppm in the zinc/organic formulations.

Operating concentrations for these chemicals in closed recirculating cooling systems may be 10 to 20 times greater than in the open systems. The use of zinc/phosphate and zinc/organic formulations as alternatives to chromates, although advocated by some suppliers, has not been widely accepted by the industry.

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The search for non-chromate, non-phosphate, non-zinc corrosion inhibitors for recirculating cooling systems is being pursued by many investigators. New formulations have been introduced by certain manufacturers towards this goal. It remains to be seen whether these formulations withstand the test of actual and continued application.

Blow-down losses from open recirculating cooling systems are controlled to maintain concentration cycles in the system in the range 4 to 6. This generally gives rise to a blow-down loss of 0.05 to 1.10 percent of circulating water rate. In large scale cooling systems, losses of chemicals via this blow-down can therefore be quite significant. Blow-down losses from closed recirculating systems seldom occur, although systems may be drained for maintenance.

In addition to seeking alternatives to zinc and chromium chemicals, some suppliers offer chemical or ion-exchange waste treatment processes for the control of chromium losses. These are only applicable to large cooling installations at present.

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Control of algae and other biological growths may be achieved by shock chlorination using chlorine or hypochlorite solution or by the addition of 40 to 50 ppm of chlorophenate or quaternary ammonium slimicide. Chlorination cannot be used for humidifiers or air washers due to safety and health considerations.

The control of fungal growths is usually achieved by the use of a broad spectrum slimicide such as methylene-bis-thiocyanate at dosages of 5 to 10 ppm for short periods.

It is common practice to alternate treatments on a weekly or monthly basis so that blow-down from the system may at any time contain a variety of biocide residues.

It is reasonable to assume that products which are designed to be toxic to algae and fungi or to inhibit the growth of these organisms will exhibit similar toxicities and adverse effects to other higher forms of aquatic life. The precise effects of many of these products on fish and other aquatic life have yet to be determined. Consequently the discharge of wastes containing these products into natural waters should be discouraged.

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There are no apparent adverse effects associated with the discharge of such wastes to municipal sanitary sewers, although the possibility cannot be entirely ruled out, and this disposal method seems to be the better alternative.

The use of chlorine chemicals and other chemical oxidants as alternatives to organic chemical biocides should be encouraged, particularly where wastes are being discharged to surface waters or storm sewers since, in spite of their toxicity, these chemicals are relatively unstable and break down quickly into innocuous by-products. Residuals of chemical oxidants in discharges to sanitary sewers would in fact be beneficial in terms of their capacity to oxidize organic matter.

It should be noted, however, that residual chlorine in the presence of ammonia can give rise to quite stable and toxic chloramines. Also, residual chlorine can be toxic to aquatic life.

Some of the chemical losses associated with waste discharges from water and waste treatment processes have already been discussed under boiler and cooling water treatments. In general, ion exchange regeneration wastes, corrosion inhibitor losses, flocculant and coagulant

losses and scale inhibitor losses have the same characteristics whether they are associated with boiler water conditioning, cooling water treatment or water and waste treatment processes. Certain specific industrial waste treatment applications of these chemicals and processes may give rise to waste discharge problems characteristic of the industry type but these will be dealt with elsewhere in this course.

This leaves general applications of chemicals in foam suppression, emulsion breaking and odour control.

As indicated previously, a variety of chemicals are employed as defoamers. Generally these chemicals are chemically inert and suppress foam by physical processes. The only defoamer which has been identified as having potential adverse effects on the aquatic environment is kerosene and its use in the pulp and paper industry has been curtailed. It is difficult to assess the significance of the remaining defoamers and this is an area for future investigation.

Emulsion breaking chemicals (demulsifiers) can give rise to contamination problems both from the chemical residual and the oil released from the emulsion.

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Consequently, these chemicals are usually employed as a pretreatments prior to some other form of physical separation to remove oil and suspended matter. Whether or not the discharge of the effluent from such a system is acceptable for disposal to a storm sewer or surface water often depends on the efficiency of the physical separation.

Of the three classes of odour control agents mentioned previously, the chloro benzenes are of most concern since they function both as bacteriocidal and odour masking agents. As such, they are significantly toxic and should only be used in situations where the discharge receives secondary biological treatment. However, care must be exercised to ensure that excessive quantities of these chemicals are not discharged to municipal sewerage systems. Since in excess these compounds may prove toxic to sewage treatment processes.

In summary, the wide variety of specialty chemicals now in use is potentially significant in terms of adverse effects on sewage treatment processes and natural watercourses. Many areas of specialty chemical usage such as boiler treatment, cooling water treatment, water conditioning and waste treatment do not pose a major

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hazard to sewage treatment processes and the disposal of wastewaters arising from such usage to municipal sanitary sewers should be encouraged as an alternative to discharge to natural watercourses. On the other hand, disposal to sanitary sewers should be regulated to ensure that sewage treatment processes are not adversely affected. Other areas of specialty chemical usage constitute more difficult problems to resolve, both from the lack of knowledge about the precise effects of certain chemicals and the absence of non-polluting alternative chemicals.

It is anticipated that these problems will be dealt with in co-operation with industry in the determination of toxic and other effects of specific chemicals and in the development of new less hazardous chemicals.

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DAIRY PROCESSING

INTRODUCTION

This presentation, under the heading of "Dairy Processing" will cover industries using milk as the raw product and converting it to such final consumer goods as cheese, butter, whole milk, buttermilk, powder milk, ice cream, etc. This paper will therefore cover cheese plants, dairies, creameries, etc., noting their operations as related to the production of wastes. The types of wastes produced will also be examined to determine their effects on municipal sewage treatment plants and the type of treatment that would be necessary to render dairy process wastes acceptable for discharge to a municipal sanitary sewer or to a natural watercourse.

The dairy processing industry represents a viable and very necessary segment of our economy since products such as milk, baby formulae, ice cream, butter, etc., still remain a basic adjunct to health. The industry in general has grown from small one-man rural operations to massive complexes requiring the services of a network of farmer co-operatives, private businesses, nationwide store chains, etc. to bring the product to market. The status of this industry has changed over the past years to a point where it is a reckoning factor in our modern economy.

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In the past there were numerous small plants scattered around the rural community producing single products largely to satisfy local demands. A butter manufacturing plant would produce this as the main product and discard as waste such by-products as skim milk and buttermilk. This type of operation became wasteful and uneconomical as larger establishments could produce a variety of products and therefore sell their goods at a lower price. Because more modern transportation means became available, whole milk and the final product could be transported greater distances to and from the rural communities. Smaller plants became uneconomical and therefore had to cease operations.

As a result of this new trend to centralize operations, larger milk producing plants are now located in municipalities where a ready labour market is available and where the wastes can be discharged to the sanitary sewers for ultimate treatment at municipal sewage treatment plants. Since these plants have become larger and have the capacity to produce a variety of products the waste discharges have become more significant since they now can have a noticeable effect on the proper operation of a sewage treatment plant.

Butter plants and condenseries are often put together

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so that cream and skim milk by-products may be utilized in one location. Similarly ice cream and fluid milk and cottage cheese plants are combined for the most efficient and utilization of whole milk. Cheese plants on the other hand are usually operated separately since they make total use of whole milk,and the main by-product whey cannot be readily converted into another economically viable commodity.

For the purpose of this discussion each product will be covered separately, noting the process operation that must be carried out to convert the raw milk to the final consumer goods. It will be pointed out where liquid wastes originate and how they may be controlled at the plant. At the end of this discussion an attempt will be made to cover the methods of treatment that are available to the industry if it chooses to handle its own waste disposal problem and the type of pretreatment that may be required to permit the discharge of dairy processing wastes to the sanitary sewer to eliminate any adverse effects on the operation of a sewage treatment plant.

PROCESS OPERATIONS & SOURCES OF WASTES

(1) Butter Manufacturing

The production of creamery butter at one time declined as a result of competition with margarine. In

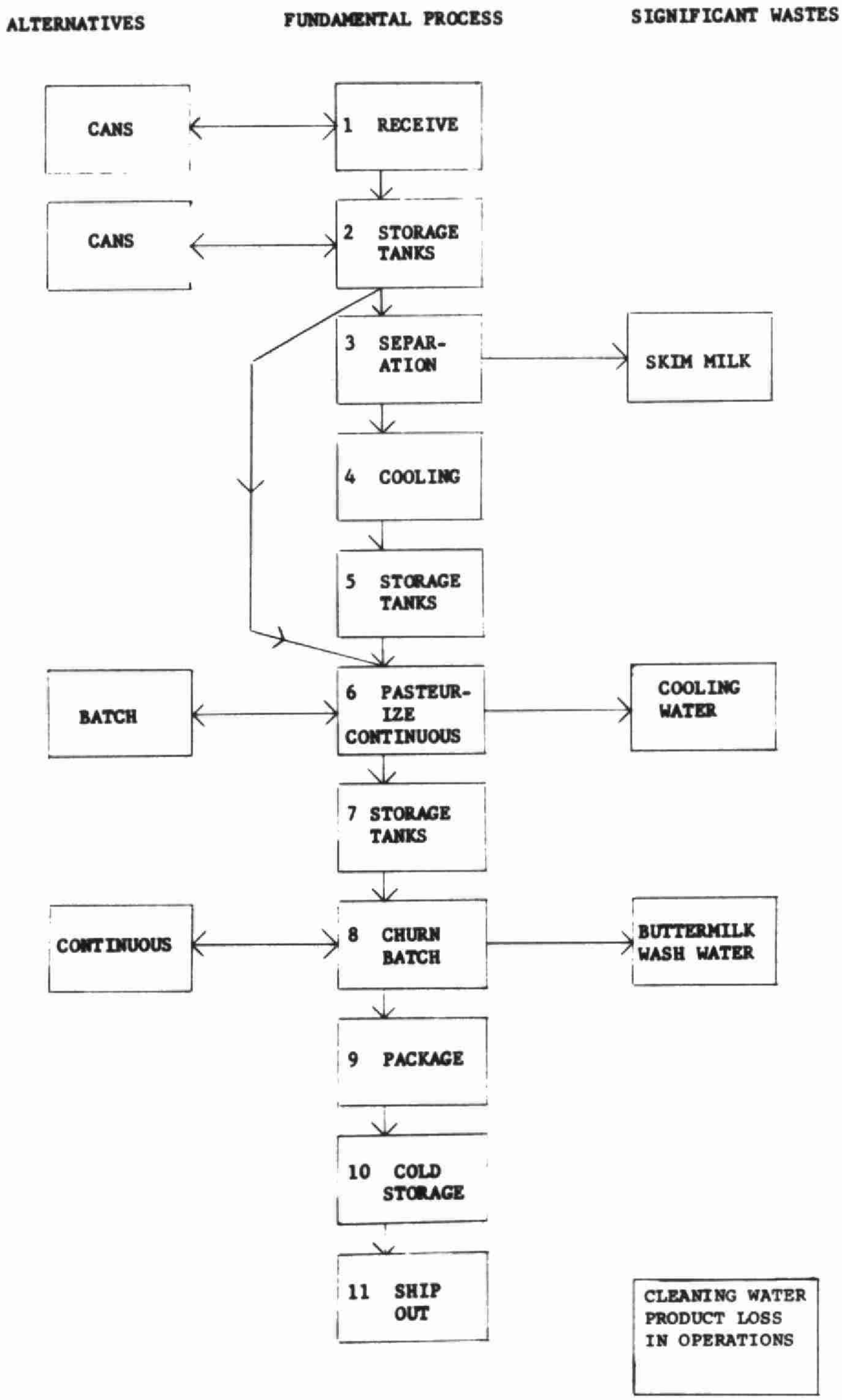
recent times however the consumption per capita has begun to increase and this trend is expected to continue, making this again a significant industry. At butter production plants raw milk (unpasteurized) is received at the plant in tank trucks (or in ten gallon cans at the smaller operations) after which it is stored in refrigerated tanks before use. The raw milk is then passed through a heater to bring the temperature up to about 90°F and centrifuged to separate the cream which normally has a butter fat content from 30% to 40%. The cream is stored separately while the skim milk is sent on as a by-product for conversion into powder milk, cheese, ice cream, etc.

The cream is cooled and depending on the size of the operation is pasteurized in continuous flow pasteurization units (larger plants) or batch pasteurization units (smaller plants). The cream is cooled once more and sent to the churning units where butter is separated from buttermilk at a temperature of about 45°F. The butter is "worked" to the desired consistency and sent to packaging. The by-product buttermilk from the churning process is sent to waste or passed on for further processing.

(See Figure I)

FIGURE I

CREAMERY BUTTER



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Milk, and other by-products such as skim milk, buttermilk, whey, etc., are received in tank cars at large plants and in cans at the smaller plants and are stored in refrigerated tanks prior to use. Cream is separated from whole milk by centrifuging for use in ice cream manufacturing. Skim milk is pasteurized and sent to the evaporators. The evaporation of the milk is carried out under vacuum to reduce the change of the product being burned or damaged by excessive heat. Smaller plants use "batch" boilers while larger operations employ multiple effect evaporators to reduce operating costs. Normally 15% of the water is removed to produce a condensed milk which can be sold in the condensed form or can be spray dried to convert it to milk powder. Spray drying involves pumping under pressure and spraying the material through a heated air screen where the remaining water is removed. The condensed milk is cooled, stored, canned in sterilized containers and shipped for marketing. Powder milk is packagedin small bags or barrels depending on its ultimate use.

The most significant sources of waste are spills and leakages associated with the milk handling operation and of course washdown waters from the cleaning operation. Product spills may contribute high BOD loadings if poor

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housekeeping techniques are used. The wash waters contain soaps, chemicals, detergent as well as some product and can contribute a significant loading on a sewage treatment plant.

Since there are numerous heating and cooling operations involved, a considerable amount of cooling water is utilized. Again since there is no contact of cooling water with product, this waste can be disposed of directly to a watercourse or storm sewer. In the evaporation step, the vacuum on the boiler is usually maintained through the use of a barometric leg condenser. This involves pumping a considerable amount of water through a venturi to create the vacuum. Normally this is clean cooling water, however, if there are upsets in the boiler and the unit "burps" some material can be transferred into the water stream and cause its contamination. The pumping arrangement on the barometric leg condenser should be set up on a flexible basis permitting the discharge of clean water to the storm sewer, and the discharge of contaminated water to the municipal system during upset conditions. FIGURE II shows the basic processes.

(3) Cheese Manufacturing

In contrast to the butter industry the cheese

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FIGURE II

CONDENSED AND EVAPORATED MILK

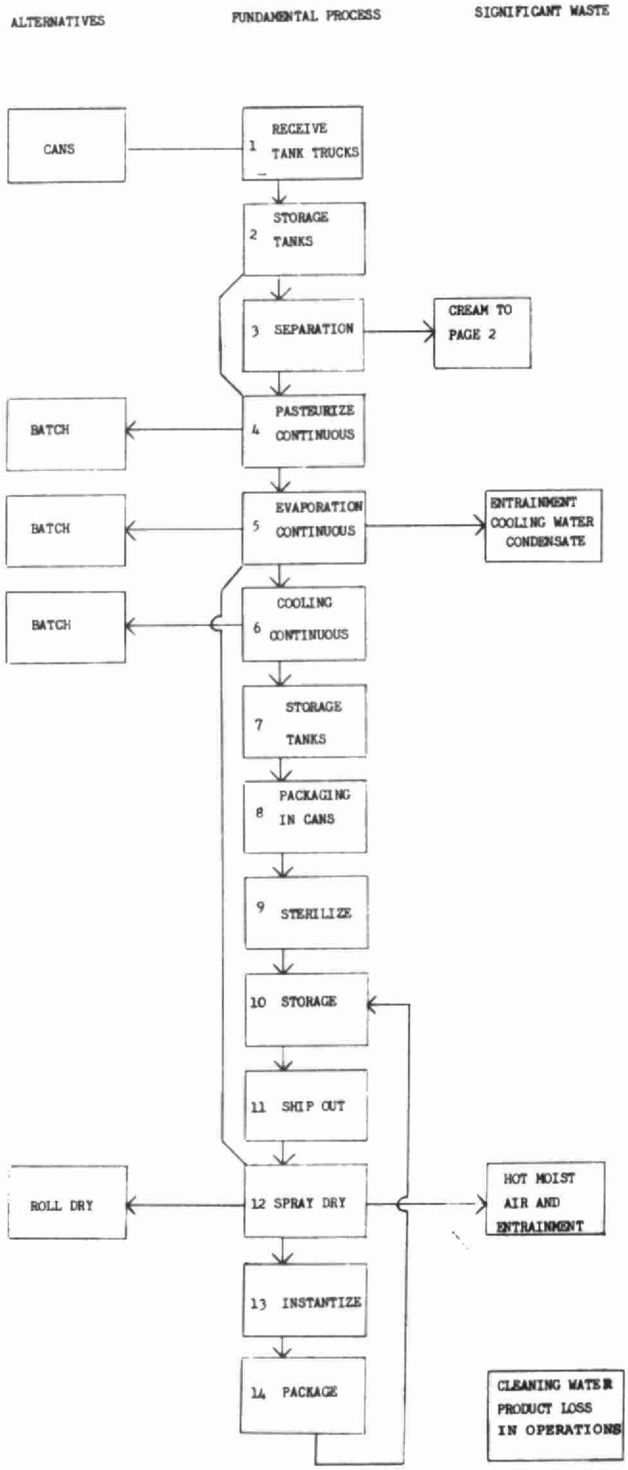

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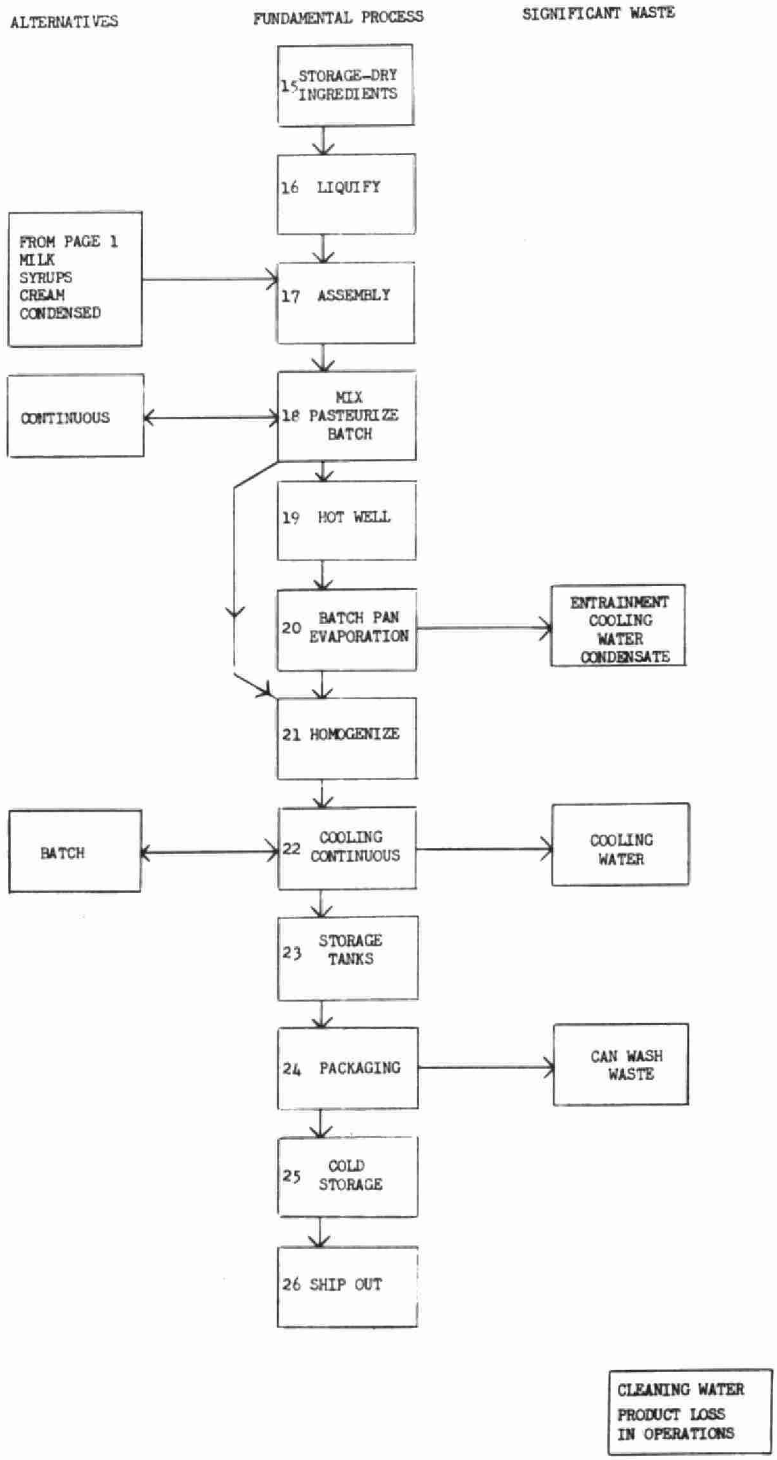
FIGURE II

CONDENSED AND EVAPORATED MILK CONTD.



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industry has grown rapidly and this expansion trend is expected to continue. In the manufacturing of cheese an extremely potent waste is produced which cannot be readily converted to an economically useful by-product and hence this industry has inherently a serious waste disposal problem.

Raw milk and skim milk are received at the plant in tank cars and are stored in refrigerated tanks ready for use. If low fat cheeses are to be made the whole milk is heated and centrifuged to remove cream which becomes a readily sold by-product. The milk is pasteurized in batch or continuous flow pasteurization units, cooled, and pumped to cheese vats. In the vats the milk is innoculated with bacteria after which the milk forms curds and whey. The curds are separated from the whey for production into cheese while the whey becomes the by-product which is either sent to waste or converted to some usable form. The curds are then rinsed with the wash waters being sent to waste. Then the curds are pressed and placed into a controlled environment to permit "aging" with the incubation period lasting anywhere from days to months depending upon the variety of cheese to be produced. The final product can then be blended into a cheese by-product or may be packaged as is. A flow sheet of a typical cheese operation is shown in FIGURE III.

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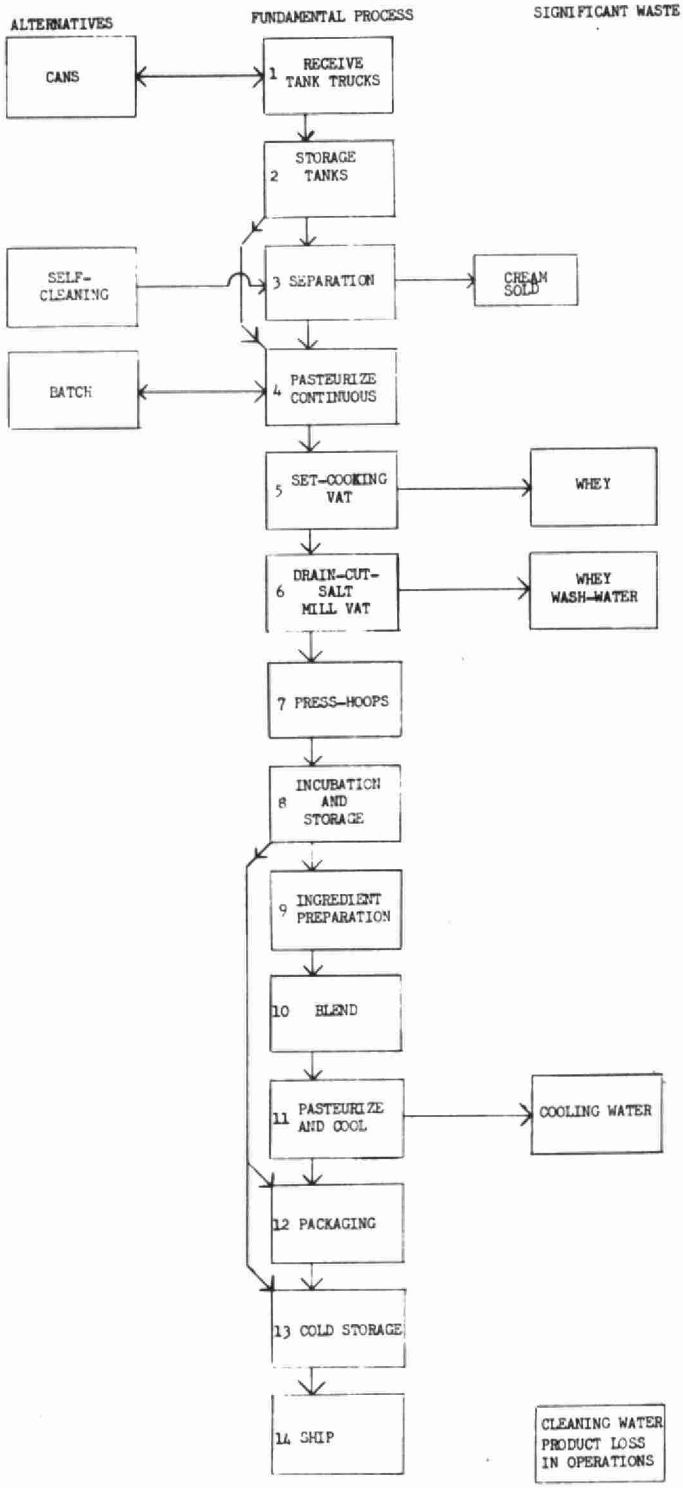
FIGURE III
CHEESE



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The refrigeration and cooling after pasteurization requires the heavy use of water. This water is never in contact with the product and hence can be discharged directly to a storm sewer or natural watercourse.

The most significant waste produced is the whey. Roughly, for every 100 lbs. of milk used in cheese production, about 90 lbs. becomes whey and 10 lbs. becomes cheese. Whey can be dried to produce a valuable by-product however, in most cheese factories the volume produced is not enough to set up a viable evaporation system. The whey in most cases is discarded as waste which results in a difficult disposal problem since this material has a BOD concentration in the order of 3.2% and has a high protein and acid content. Rinse and wash waters used to wash the curds also contains some whey and therefore has a high BOD and suspended solids concentration.

Some of the other significant sources of wastes are spillages associated with milk handling operations and the wastes produced during the washing down of equipment. Although not as difficult to handle as whey, these wastes still contain high concentrations of BOD and milk-type solids and these require some degree of treatment

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whether at a municipal plant or at the industry prior to discharge to a watercourse.

(4) Ice Cream & Frozen Desserts

The ice cream and frozen dessert industry has grown steadily over the past years and this pattern is expected to continue in the future. These plants also reflect the population patterns and hence they trend towards larger plants located in built-up municipalities. Modern transportation methods have permitted this industry to distribute products over a wider area. FIGURE IV shows the basic manufacturing processes.

Raw milk received at the plant in tank trucks is sent to a refrigerated tank for storage until use. The ingredients such as stabilizers, emulsifiers, sugars, etc., are blended together according to the formula of the product. The mix is pasteurized and then homogenized to mix up and break up the fat particles so that they may remain in suspension, after which the mixture is cooled and sent to storage. From storage the material passes through another blending operation where nuts, fruits and flavours are added to make the finished item. The mixture is finally frozen to make the ice cream and/or frozen dessert which is packaged for distribution.

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FIGURE IV

ICE CREAM AND FROZEN DESSERTS

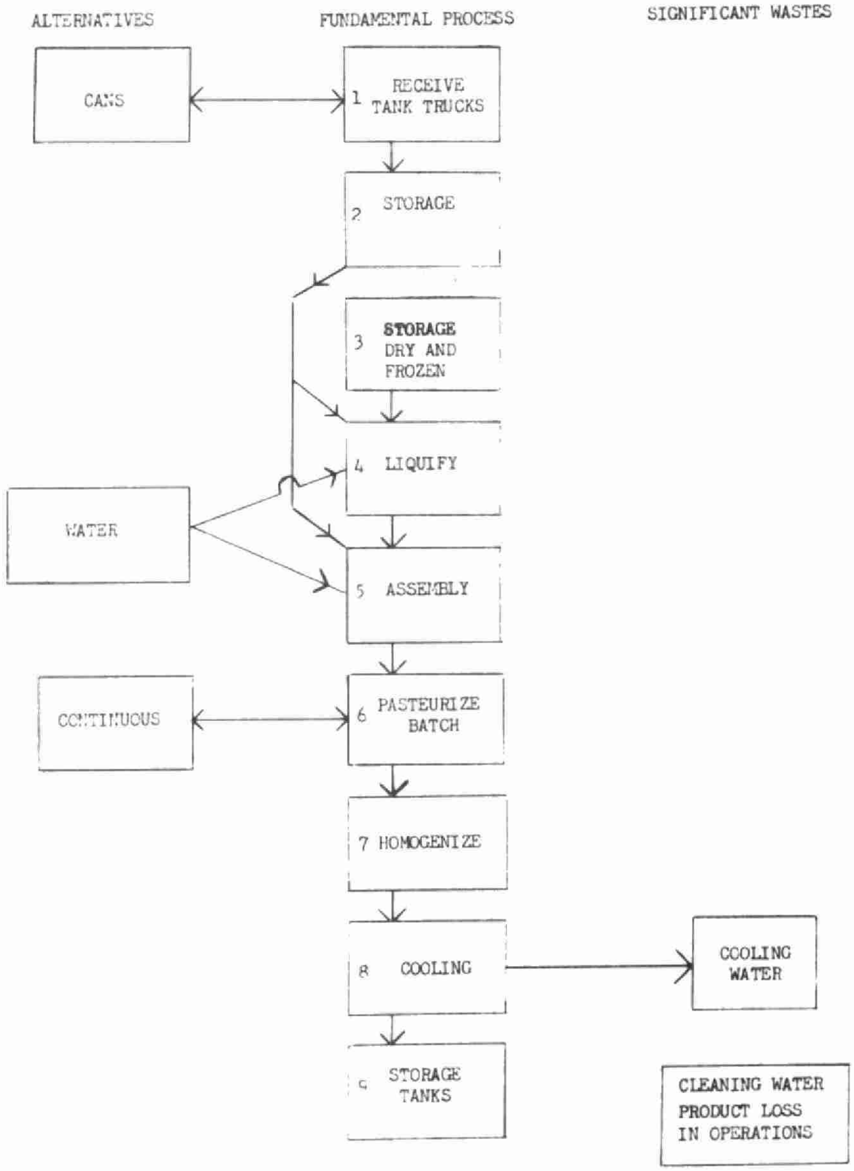

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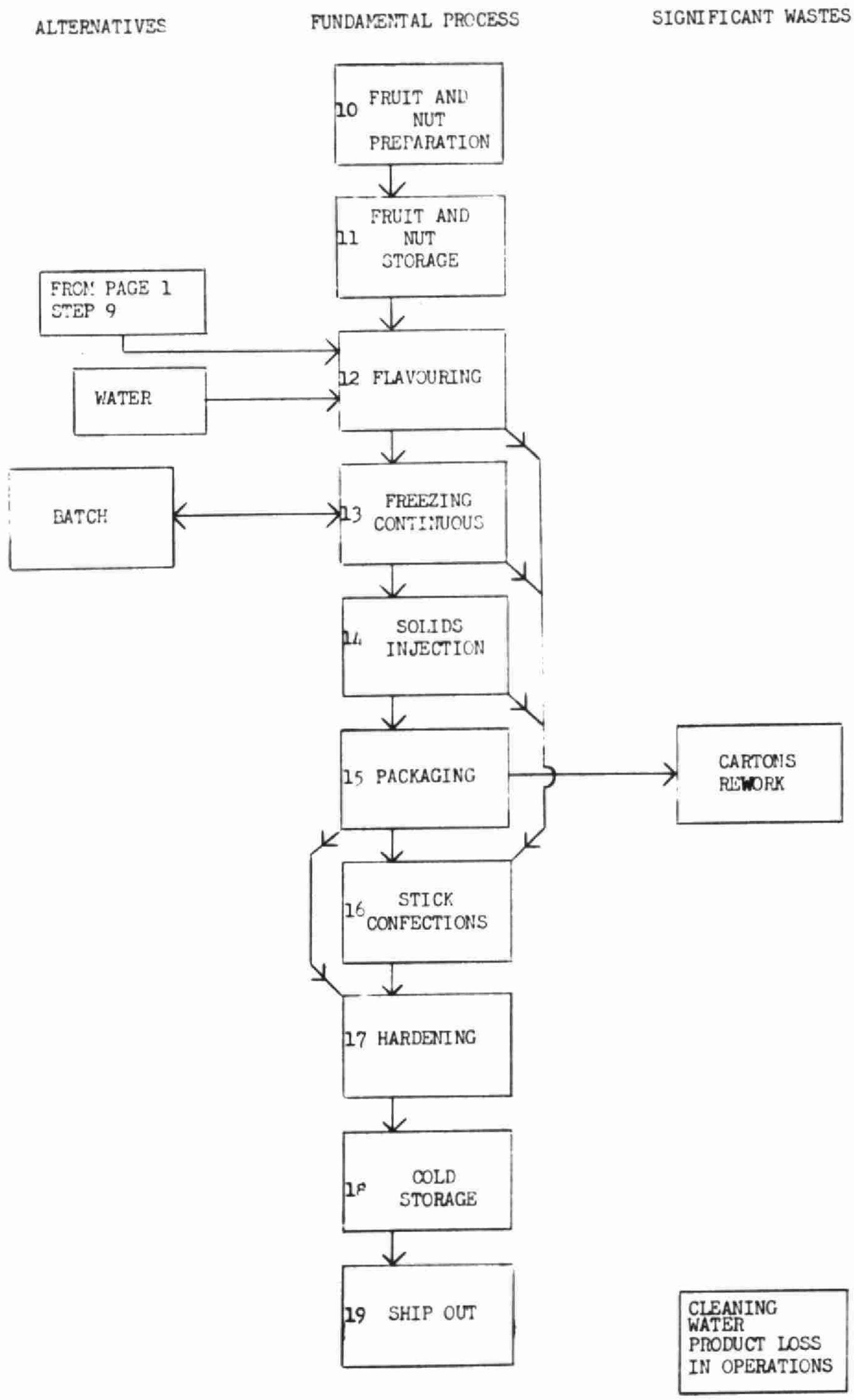
FIGURE IV

ICE CREAM AND FROZEN DESSERTS CONTD.



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Again the sources of wastes are leaks and spillages and the wash waters used to clean equipment. These wastes require some form of treatment prior to discharge to a watercourse. Because these plants are located in municipalities, treatment usually takes place in a municipal sewage treatment plant. The cooling waters are normally uncontaminated and acceptable for disposal to a storm sewer or directly to a watercourse.

(5) Fluid Milk

Fluid milk establishments are primarily engaged in the production of milk itself and associated products such as skim milk, 2%, etc., and cottage cheese as a normal side-line. The fluid milk industry has expanded over the past years and this trend is expected to continue as population growth increases. Because of better means of transportation larger plants are being constructed in municipalities, distributing their products over wider areas.

Raw milk, normally received in tank trucks or in 10-gallon cans is pumped to refrigerated storage tanks prior to use. The milk is then clarified (strained) in centrifuge devices or in smaller plants, through the use of small mechanical filters. The milk is then

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pasteurized in continuous flow pasteurization units or in batch type units in smaller plants. The pasteurized milk is then homogenized to break up the butter fat particles so that they may be kept in a suspension in the liquid. In some cases it may be necessary to "deodorize" the milk to remove any off-odour or off-flavours. This is done by subjecting the milk to vacuum steam injection in bad cases or simply using a vacuum treatment in milder cases. After this treatment the milk is cooled and sent to storage and then to packaging. Milk can be packaged in bottles, cardboard box units, plastic containers, etc., after which it is sent to cold storage prior to distribution.

The fluid milk plants also produce cottage cheese as a by-product. The pasteurized milk is cooled to the desired "setting" temperature and pumped into cheese vats where it is innoculated with a bacteria culture. At the end of a controlled period of time the curds are separated from the whey, cut into small pieces and cooled. The whey is discarded as waste or sent on as a by-product for further processing. The cheese is dressed with cream, milk or fruits, and packaged ready for distribution. A flow sheet of the operations for a fluid milk plant is summarized on FIGURE V.

FIGURE V

FLUID MILK

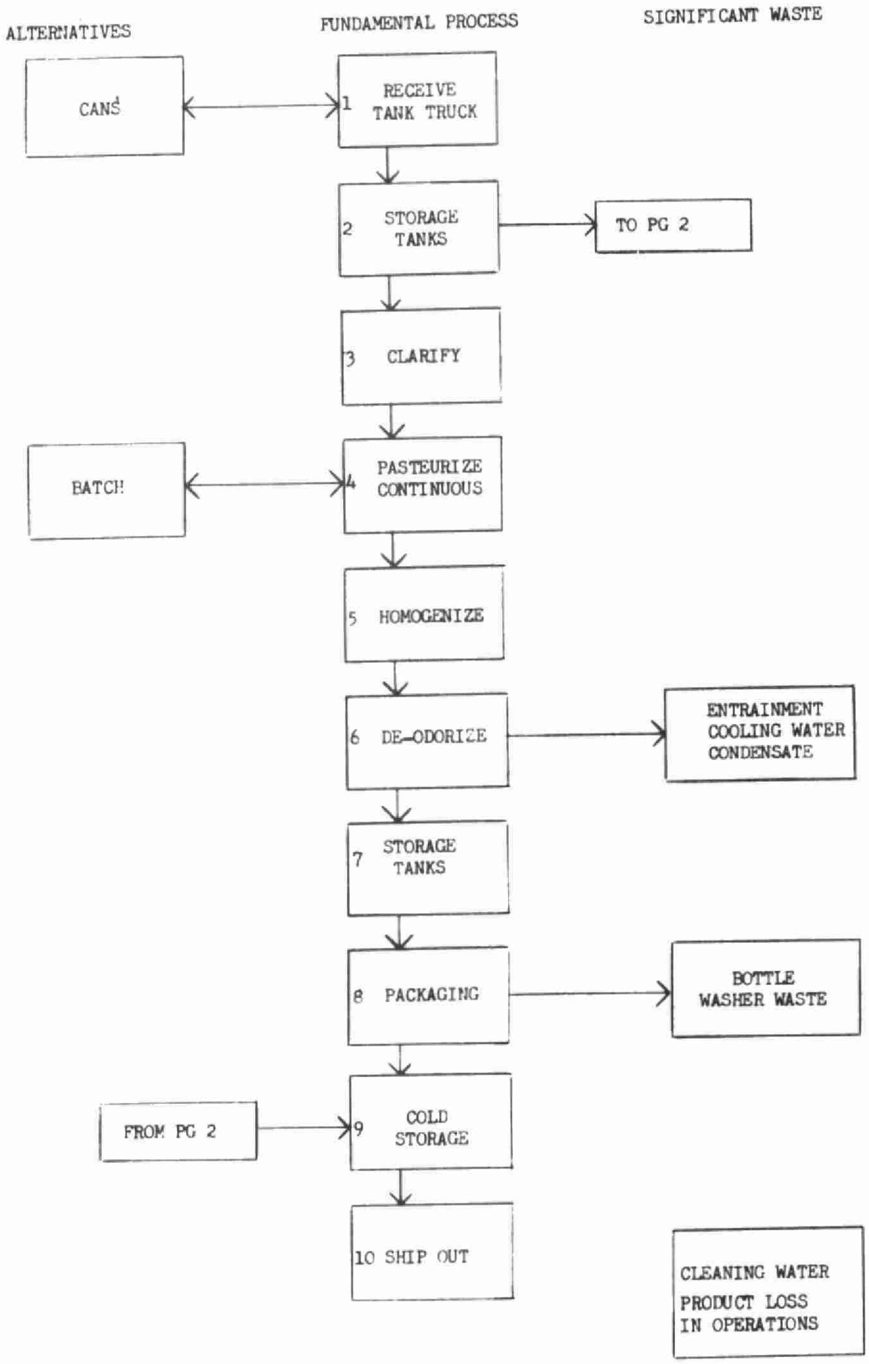

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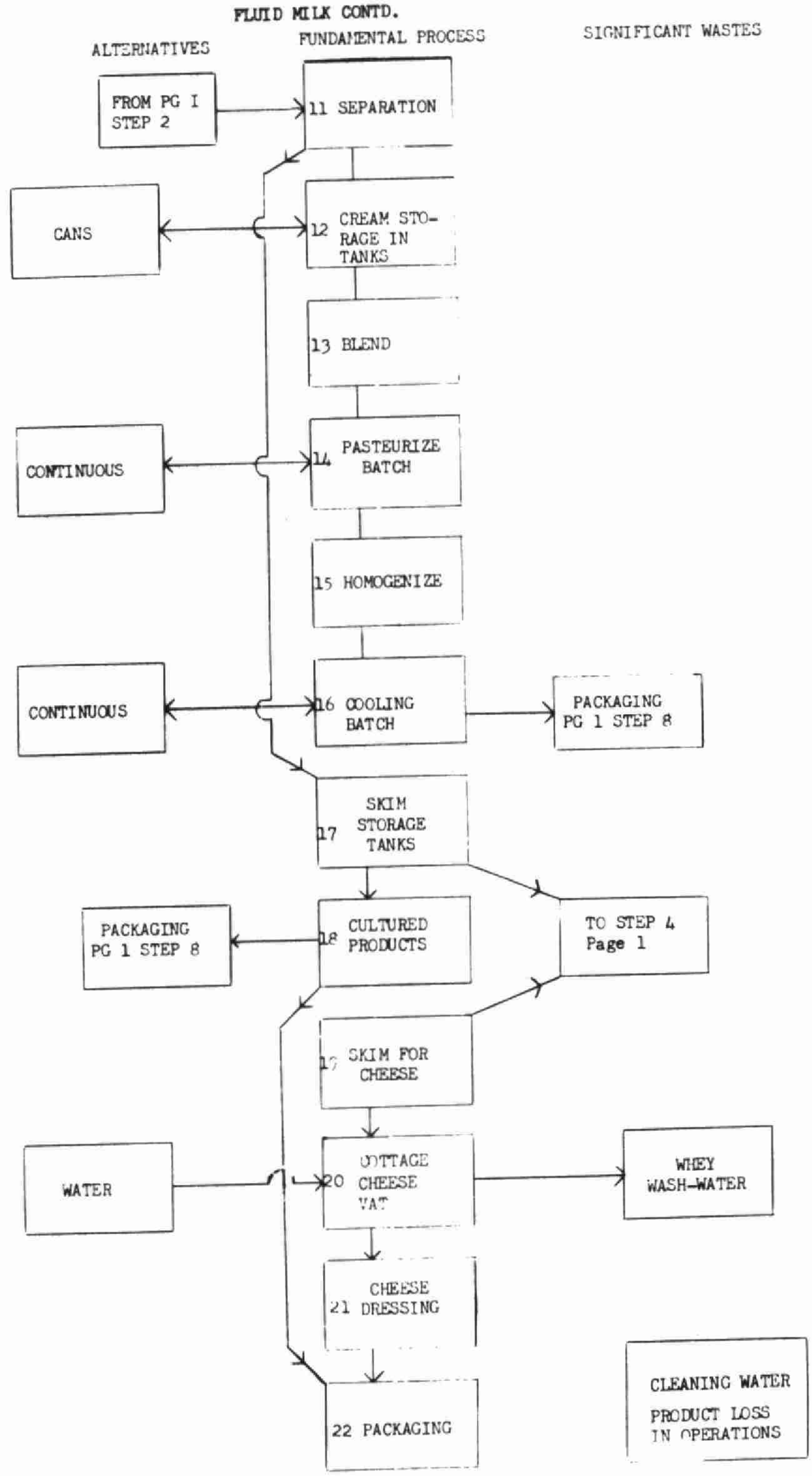
FIGURE V

FLUID MILK CONTD.



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WASTE HANDLING & DISPOSAL

In-Plant Control

The first control procedure that any company should consider is to adopt good housekeeping practices regardless of whether the wastes are to be treated privately or discharged to the municipal sanitary sewers. Reducing product losses to the sewer by minimizing spills, leakages, bottle breakages, etc., is extremely important in the Dairy Industry since even minor losses of milk to the sewer can affect the quality of the final effluent. Cooling waters from pasteurizers, compressors, and refrigeration units should be segregated and discharged to a storm sewer or watercourse to reduce hydraulic loadings on the treatment system. These wastes do not come in contact with product and hence are uncontaminated and acceptable for direct disposal to a watercourse.

Some of the more recent developments in the industry have helped to increase production and at the same time reduce waste flows. A higher percentage of the milk is now received at the plants in tank trucks rather than in 10 gallon cans which has the tendency to reduce spillage and the amount of water used in the cleaning operation. The change from batch operations to continuous flow operations had produced wastes having a more consistent

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quality and has reduced the frequency of washing down equipment. The packaging operations have become more sophisticated and spillages have been reduced considerably. The packaging of milk in paper cartons has reduced the need of washing out bottles returned to the dairy for re-use. Also in this modern economical climate smaller operations have shut down to be replaced by larger plants located in municipalities. More efficient larger plants can operate at a higher profit margin and can better afford to install wastewater control measures.

Since dairy wastes are organic in nature they can and do exert a high BOD demand. The material exerting the oxygen demand is in a soluble form which cannot be screened out or settled out in conventional sumps (except for organic matter in cheese plant wastes). Dairy wastes cannot normally be treated in the primary section of a treatment plant and hence any batch discharge to the sanitary sewer would exert an immediate loading on the aeration section. To prevent these extreme shock load effects the dairy industry must provide some form of control at the plant.

The company should be expected to provide equalization facilities to mix these wastes and permit the

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discharge of a more uniform quality effluent to the sanitary sewer. In this regard it would be even better if the wastes could be stored during the day and discharged to the sewer at night when the municipal facilities are not being taxed as heavily by normal sanitary waste flows. Good in-plant control and waste equalization are perhaps the two simplest control measures that could be adopted by the industry to render the wastes acceptable for discharge to a sanitary sewer.

Pre-Treatment

As may be expected, any pre-treatment systems that are available to the industry are similar to those for other organic wastes. Because dairy processing wastes are quite amenable to biological treatment, as a quick rule of thumb, the solution has always been to discharge them to a sanitary sewer for ultimate treatment at a sewage treatment plant.

Dairy processing wastes put a direct and almost immediate load on the aeration works and hence it is imperative to determine the exact waste loading contributed by the industry. After all in-plant control measures have been implemented, and good equalization of wastes is being effected, it must be decided whether

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the sewage treatment plant has the necessary capacity to handle the industry's loading. If there is insufficient capacity the industry will be required to provide pre-treatment to reduce this loading so that it can be handled satisfactorily at the sewage treatment plant. The type of pre-treatment system to be installed, and the degree to which the wastes are to be treated, depend entirely on the type and capacity of the sewage treatment plant. The type of pre-treatment would of necessity be of a biological nature and can be listed as follows:

(1) Trickling Filters

The trickling filter can be used quite effectively to provide rough treatment of organic wastes, and render the effluent acceptable for disposal to a sanitary sewer. Dairy processing wastes are readily biodegradable which allows a reduction in the size of the treatment units. In Ontario, trickling filters have not been popular since it is said that treatment suffers during winter operations. In the case of dairy wastes, these units may be quite small and hence can be easily installed under cover, eliminating problems associated with winter operations.

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(2) Aerated Lagoons

The aerated lagoon can also be used for roughing purposes to reduce the waste loading from the dairy industry to levels acceptable for discharge to a sanitary sewer. This constitutes constructing a lagoon and providing some form of aeration. Air may be introduced into the wastes by means of high or low speed surface aerators, diffusers, blowers, etc. The designs of these systems can be varied considerably depending upon the degree of pre-treatment required.

Complete Private Treatment

The industry may wish to install its own wastewater treatment system and discharge the wastes to a storm sewer or watercourse rather than to a sanitary sewer. Here the handling methods are more varied and can be summarized as follows:

(1) Land Disposal

(a) Spray Irrigation

In this instance wastes are collected, screened and applied on land through a series of lines and sprinklers. Dairy wastes are suitable for land disposal, but care must be taken not to overload the land from a hydraulic point of view. Dairy wastes in particular can turn septic quite easily and can cause odour and nuisance problems. Sufficient land must therefore be

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available to keep application rates as low as possible.

In winter when it is impractical to spray the wastes the company may be required to provide a storage lagoon to retain all wastes produced during winter operation. These wastes can then be sprayed on land starting in early spring as weather permits. These lagoons can be a source of odour in spring when the ice cover breaks up but this is normally a temporary condition and should not last for more than one week. Masking agents and nitrates may be used to overcome some of these odour problems.

(b) Ridge and Furrow

Ridge and furrow can also be used as an effective means of land disposal providing minor modifications are made to the system. Essentially the furrows should be longer and shallower to reduce the time the wastes stay as puddles in the furrows. This of course is to prevent any septic conditions from developing. The furrows may also have to be plowed more often since fats in the milk could seal the sides of the furrows and prevent the wastes from leaching into the ground.

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(c) Haulage & Spreading on Land

In some very small operations the wastes can simply be collected at the end of the day, hauled away and spread on land. Again it is necessary to insure proper application to prevent ponding and subsequent odour problems. It has been the favourite practice of cheese plants to spread whey on rural roads to cut down dusting problems.

(2) Biological Treatment

There are a number of biological systems available to the industry that are capable of producing an effluent acceptable for discharge to a natural watercourse. These systems are more complex requiring a substantial expenditure both for capital and operating costs. Because of this these types of facilities are normally installed by the larger industries.

(3) Aerated Lagoons

Aerated lagoons with sludge recycle have been extremely effective in treating dairy processing wastes in Ontario. The sludge is normally settled in clarifiers and returned to the aerated section. Various means have been used to introduce air into the wastes however it appears that surface aerators are the most popular.

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(4) Oxidation Ditches

Oxidation ditches can also be used to treat dairy processing wastes. Initially problems had been encountered with the bushings at the end of the rotors. These problems have now been overcome and these systems have now become very effective.

(5) Activated Sludge

Conventional activated sludge plants have also been constructed to treat dairy processing wastes. These systems are complex and expensive and are normally installed by the larger industries.

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TANNERIES

Tanning is the process by which a skin is brought to a stable condition in which it will not putresce. In addition, tanning improves certain properties of the material such as resistance to abrasion and heat, flexibility and resistance to damage from cycles of wetting and drying.

The skin as removed from the animal consists of three layers, the epidermis, the corium and the flesh. The epidermis and flesh are not suitable for leather-making and are therefore removed. The corium consists mainly of a protein, collagen, and it is the reaction of this protein with tannin or chromium which results in the formation of leather.

When the skin is removed from the animal, it must be cured as soon as possible to prevent bacterial attack and this is normally done by covering the hide with salt. The salt removes water from the hide and it is this dehydration which is responsible for preserving the skin.

At the tannery, there are four main processing areas, the hidehouse, the beamhouse, the tanyard and the finishing department and a short description of the operations carried out in each follows:

HIDEHOUSE

Cured hides are received and are stored until required. Normally in processing hides from large animals, it is customary to cut them into two or more sections for ease of handling. Commonly, the hides are split lengthwise into sides and at the same time unwanted parts are trimmed off. The sides are then made up into "packs" of approximately 5,000 lbs, each pack being processed through the tannery as a unit.

BEAMHOUSE

Three main operations are carried out in the beamhouse, these being:

(1) Soaking

Soaking is to restore natural moisture abstracted by the salt used in curing. Soaking is carried out in vats equipped with rotating paddles which move the hides around in the soak water. Dirt, manure, blood, salt, fat, etc. are also removed during soaking.

(2) Unhairing

Unhairing is to remove hair, epidermis and certain unwanted proteins. Unhairing is carried out in a solution of lime and sodium sulphide which removes

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or dissolves the hair according to the strength of the solution, the temperature and the amount of agitation.

(3) Fleshing

Fleshing is to remove flesh and fat which may be present. This operation is carried out on a machine with rotating blades which scrape off the unwanted material. Note that fleshing may be carried out before unhairing.

TANYARD

After the beamhouse operations, the hides are free of hair, clean and are somewhat swollen by the alkali used in unhairing. Tanyard operations are as follows:

(1) Bating

Bating is to remove skin substances which do not form leather. This is accomplished by the use of enzymes (bates) similar to those found in the digestive system of animals, but before the bate is added the alkaline unhairing chemicals which are still present in the hide must be removed. This is known as de-liming and the process is assisted by the addition of certain chemicals. When de-liming is complete,

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the bate is added and is allowed several hours to work, after which the hides are washed with water. Note that some modern bates are mixtures of de-liming chemicals and enzymes so that the bating process can be carried out in a single step.

(2) Pickling

Pickling is to place the hides in an acid condition ready to receive the tanning material. An acid pH is required since the chrome tanning chemical is not soluble in alkaline conditions. Any of a number of acids may be used, but before the acid is added salt must be introduced to prevent a condition known as "acid swelling".

(3) Tanning

Tanning is to convert the hides into a stable non-putrescible material. Although many materials will combine with skin protein to form leather, certain chromium salts are most commonly used. However, vegetable tannin and synthetic tanning agents such as phenolsulphonic acid-formaldehyde complexes are also used. The solution of tanning material is added to the hides in a drum which is rotated during the tanning process.

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(4) Wringing

Wringing is to remove excess water from the leather. This is done on a machine having two wringer rolls through which the leather is fed.

(5) Splitting and Shaving

Splitting and shaving is to adjust the thickness of the leather to that required for a given end use and to achieve uniform thickness. The splitting machine consists of a horizontally moving blade which slices the piece of leather. The grain (outer) side of the leather is of uniform thickness while the flesh side (called a "split") may vary in thickness. Although the split has no grain, it may be used to produce sueded leathers. Shaving is done on a machine similar to a fleshing machine and is used to adjust overall thickness to exact specifications.

(6) Retanning

Retanning is to impart to the leather the desirable properties of the retanning agent. Retanning is carried out in the same manner as the original tan.

(7) Colouring

Colouring is to impart colour to the leather

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(8) Stuffing and Fatliquoring

Stuffing and fatliquoring is to lubricate the fibres for flexibility and softness. The leather is rotated in a drum either with liquid oils or with an emulsion of oils in water. The former is known as stuffing and the latter as fatliquoring. The softness of the leather, its flexibility and its water repellence can be controlled by selection of an appropriate type and quantity of oil or fat.

With the above step, the wet processing of the leather has been completed and the remaining steps involve the use of little or no water.

FINISHING

Finishing of the leather includes many processes designed to enhance the qualities of the leather.

The steps in leathermaking are shown in TABLE A in the order normally followed in a cattleskin tannery.

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TABLE A

PROCESS FLOW

Wet Operations

1.	Trimming and Sorting	Hidehouse
2.	Soaking)	Beamhouse
3.	Unhairing)	
4.	Fleshing)	
5.	Bating)	Tanyard
6.	Pickling)	
7.	Tanning)	
8.	Wringing)	
9.	Splitting and Shaving)	
10.	Retanning)	
11.	Colouring)	
12.	Stuffing or Fatliquoring)	
13.	Setting Out)	

Dry Operations

14.	Drying)	Finishing
15.	Conditioning)	
16.	Staking)	
17.	Buffing)	
18.	Finishing)	
19.	Plating)	
20.	Measuring)	
21.	Grading)	

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From the foregoing brief outline of the tannery processes, it will be apparent that a great deal of water is used to which is added a number of materials, all of which appear in the wastewater in varying concentrations depending on the purpose of the material and the conditions under which it is used. In addition, contaminants originating in the hides themselves are added to the waste stream, including dirt, manure, urine, blood, lymph, fat and flesh, hair and protein. In addition there is the salt used in curing the hides. It is clear, therefore, that the wastewater from a tannery will impose a large loading upon a municipal sewage treatment plant. In fact, in the majority of cases the waste loading will be so great that pretreatment at the tannery will be required to ensure compliance with by-law limits. To illustrate this point, some of the characteristics of a typical tannery wastewater are compared with a typical by-law in TABLE B.

The tannery wastewater characteristics shown in TABLE B refer to the combined and equalized flow from all wet processes. However, since the tanning process is essentially of a batch nature, there may be a wide variation during the processing day and it is desirable to know the origin of the main contaminants. Figure I

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TABLE B

COMPARISON OF TANNERY WASTEWATER WITH A TYPICAL BY-LAW

	BOD	SOLIDS			Chromium	Sulphide	Ether Solubles	pH
		Tot.	Susp.	Diss.				
Tannery	2600	10530	2320	8210	75	50	0	8.4
Tannery	1500	5150	1570	3580	52	75	152	5.9
Tannery	1700	4830	1300	3530	8	25	82	6.6
By-law	300	-	350	-	3	2	150	5.5 -9.5

All above are in parts per million except pH

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is a schematic flow chart showing the materials likely to be found in the wastewater produced at each wet processing state. It will be seen that a number of different chemicals are used in the process and appear in the effluent but fortunately only a few are of concern in cases where the effluent is discharged into a sanitary sewer system. For simplicity, consideration of the effluent characteristics may be restricted to BOD, solids, chromium, sulphide, ether soluble material and pH. TABLE C is a table showing the relative contribution of each of the processing steps to the total waste loading in terms of these components. Note that the figures given are very very rough estimates since there is a wide variation in the methods of sampling and analysis. The figures, however, do indicate the areas where the largest contribution of each contaminant occurs.

As already stated, tanning is largely a batch process and it follows, therefore, that dumps of wastewater of widely differing characteristics will occur throughout the processing day. For example, the hairburn solution may have a BOD of 10,000 - 15,000 ppm and a pH of 12, whereas the spent chrome tan liquor may have a BOD of only 2,000 ppm but a chromium content of 1,000 ppm and a pH of 3 or less. It is obvious that if each type

FIGURE I

SCHEMATIC FLOW CHART

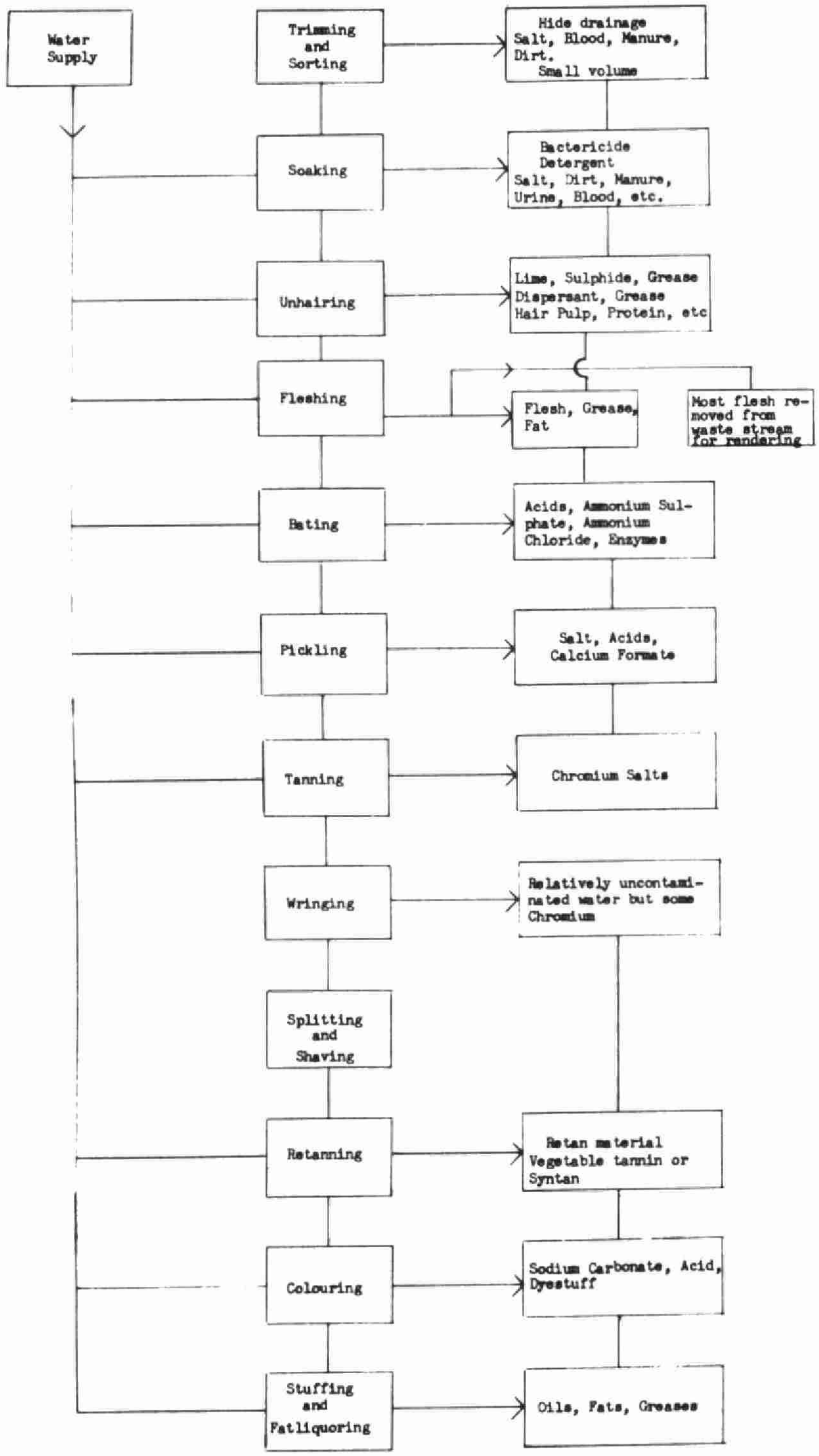

TABLE C

RELATIVE CONTRIBUTIONS TO WASTE LOADING

Process	% of water use	% of BOD	% of Solids	% of Chromium	% of Sulphide	% of Ether Solubles
Soaking	18	18	30	-	-	25
Unhairing	24	45	40	-	99	50
Fleshing	2	5	10	-	trace	20
Bating	20	15	10	-	trace	trace
Pickling	5	4	1	-	trace	trace
Tanning		4	1	95	trace	trace
Wringing	1	trace	trace	5	trace	trace
Retanning						
Colouring	20	7*	6	-*	-	5
Fatliquoring						
Finishing and Miscellaneous	10	2	2	-	-	trace

* Depends on the type of retan

of wastewater is discharged into the sewer as it is generated in the tannery, severe problems will occur in the sewers and in the treatment plant. In addition, the tannery effluent will be in gross non-compliance with the sewer-use by-law.

It is clear that tannery wastewater cannot be discharged into a sanitary sewer system unless some form of pretreatment is provided to reduce BOD and solids content, remove sulphide and chromium, regulate pH, reduce ether soluble material concentration and equalize flow. It may be desirable in fact to regulate the flow to a constant rate over 24 hours, no matter what the actual schedule of operations is within the tannery itself.

Now, certain portions of the wastewater may be used for mutual treatment, as in the case of hairburn and tanning solutions. The hairburn dump with its high pH and excess lime will treat and be treated by the pickling/ tanning dump with its low pH and excess chromium. Some of the lime will be used up in precipitating the chromium and the pH will be brought within the by-law limits. However, before this can be done, these different types of wastes must be brought together. This may be a problem

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since the operating schedule of the tannery may demand that both types be dumped at different times. The simplest solution of course is to collect an entire day's production of wastewater in a lagoon, mix it up and adjust conditions as necessary but this is impractical in most cases due to a lack of space to accommodate a large treatment facility. Therefore, the strong solutions of opposite types must be segregated, collected and held until it is practicable to treat them. Since the pickle/tan spent liquor is of relatively small volume, it may be held in a storage tank and discharged into the waste treatment plant at the same time as the hairburn dump. If, however, it is necessary (as it almost always is) to remove sulphide from the waste stream, the hairburn dump should be treated, perhaps by catalysed oxidation of the sulphide, before it is mixed with the remainder of the wastewater.

The mixed wastewater should then be treated to remove BOD, solids, chromium and grease. Clarification should be the first step since this will remove most of the solids, most of the chromium, some of the ether soluble material and some of the BOD. Mixing the wastewater before clarification will normally ensure that the pH is in the correct range since at most tanneries,

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combining the acid and alkaline wastewaters will result in a pH between 8 and 9. Should this not be the case, however, the pH may be adjusted by adding an appropriate chemical.

In some cases, clarification may be sufficient treatment to meet the by-law limits but usually some further removal of BOD is required. Where limited space is a consideration, the activated sludge system probably is to be preferred, although a trickling filter might also be used to advantage. Where space permits, lagoons or oxidation ditches may be considered.

Figure II is a flow chart showing typical steps required in minimum treatment of tannery wastewater. The purpose of keeping separate the chrome tan liquor is to allow it to be discharged into the wet well at the same time as the hairburn wastes.

The steps outlined in Figure II are the minimum and in many cases more sophisticated treatment will be required to ensure compliance with by-law limits. Figures III and IV show more advanced systems.

The treatment steps outlined in Figure IV will result in an effluent of a quality which will meet the terms of

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FIGURE II

WASTEWATER TREATMENT FLOW CHART

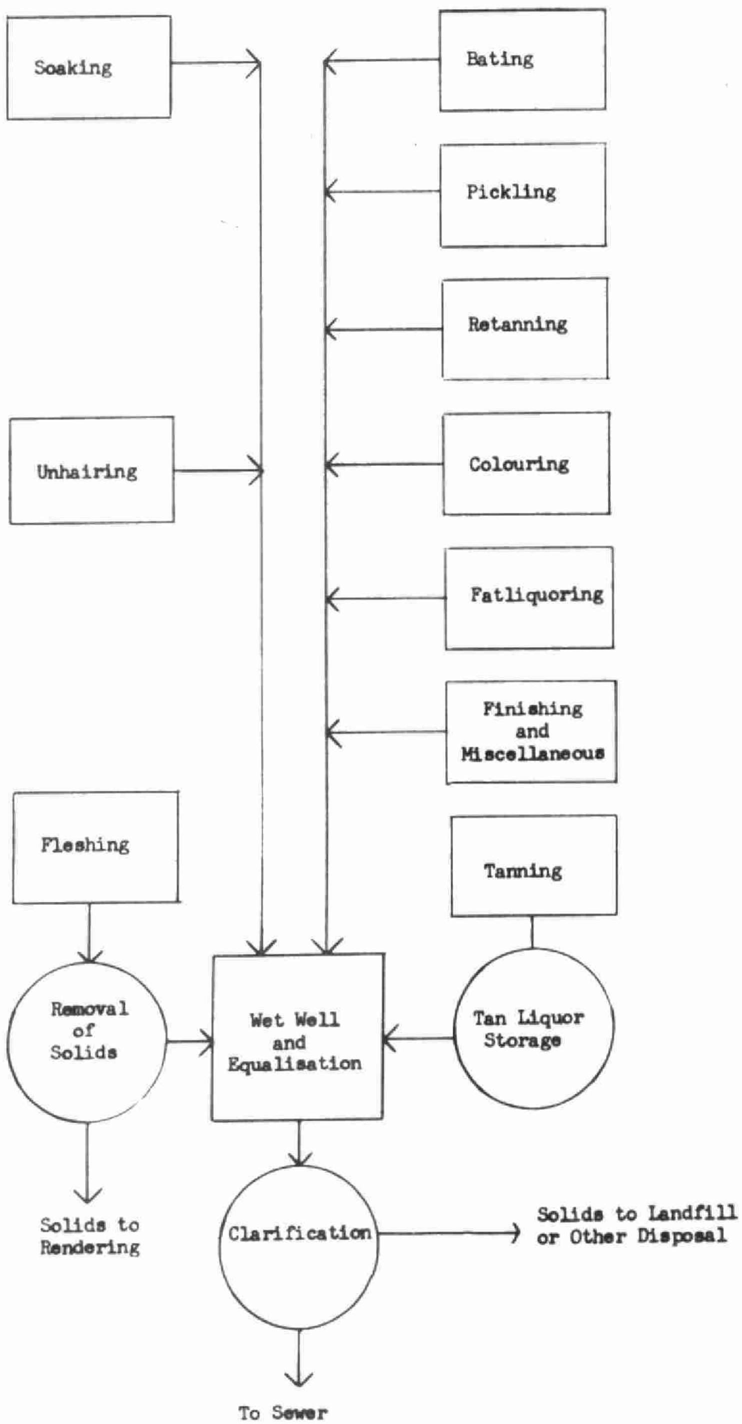

FIGURE III

WASTEWATER TREATMENT FLOW CHART

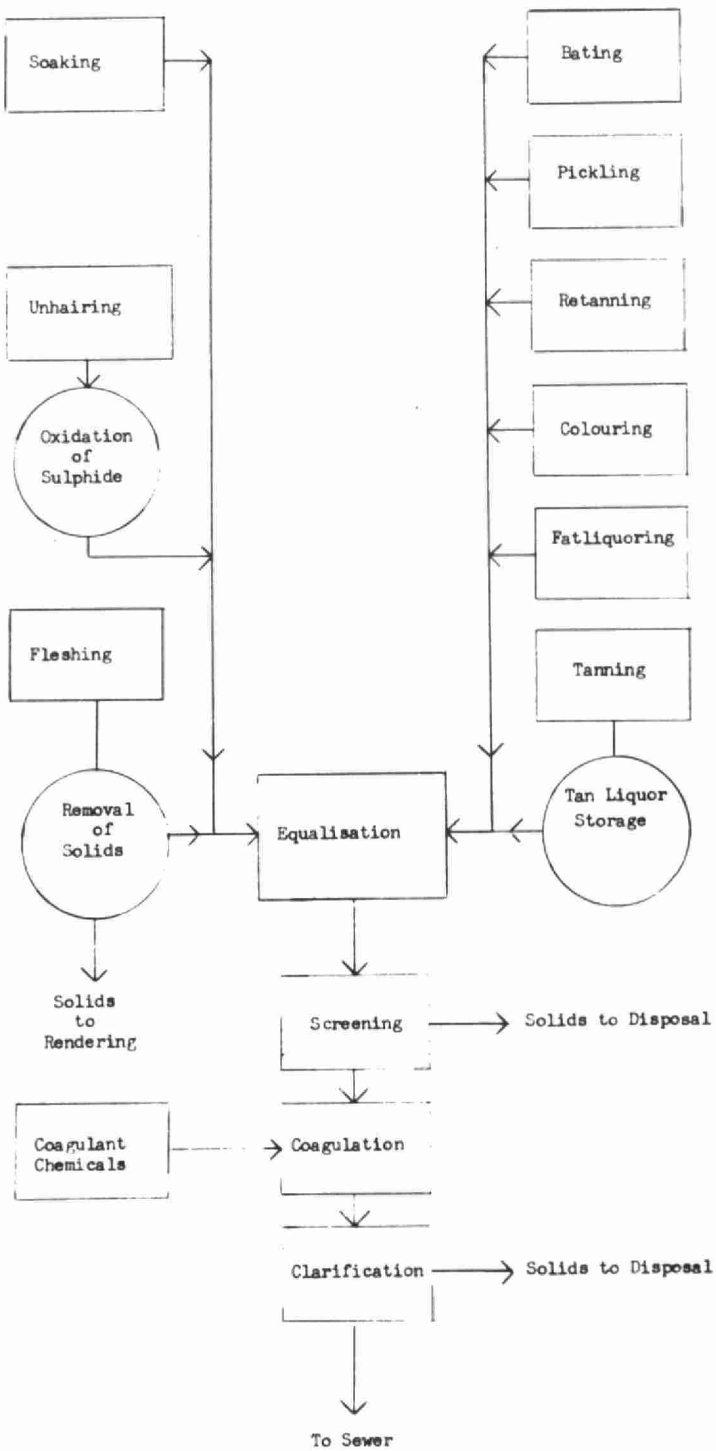

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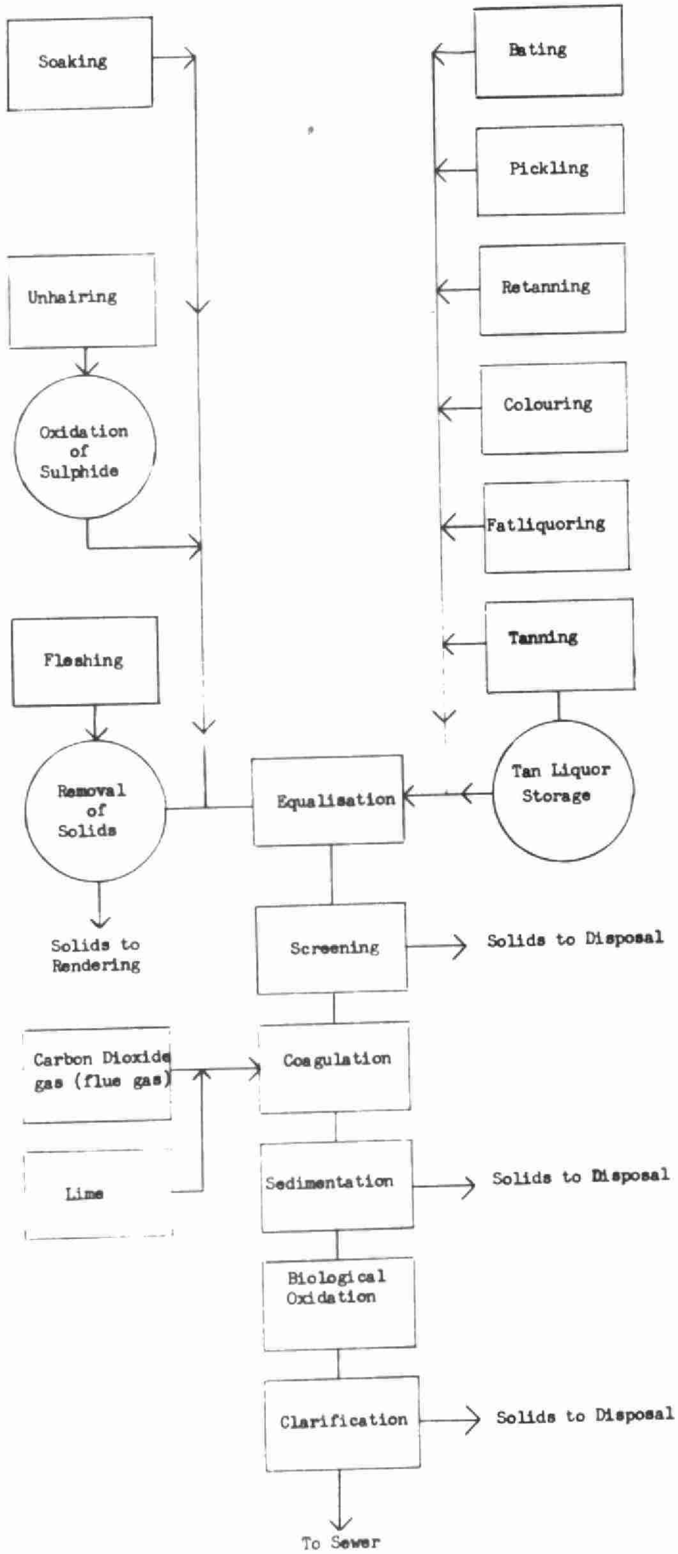
FIGURE IV

WASTEWATER TREATMENT FLOW CHART



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the most restrictive by-law. TABLE D shows the efficiency which can be expected of various treatment steps in removing contaminants from the waste flows.

TABLE D

TREATMENT EFFICIENCIES

Treatment Step	Percentage Reduction of Contaminant				
	BOD	Susp. Solids	Chromium	Sulphide	Colour
Screening	5	5-10	0	0	0
Sedimentation	25-60	70-95	5-30	5-20	5-10
Coagulation	40-70	70-97	50-90	15-50	6-90
Activated Sludge	85-95	80-95	50-75	75-100	75
Sulphide Oxi-dation	5-10	0	0	75-99	0

It is obvious that with the correct combination of treatment steps there is no reason why any tannery need produce a wastewater which does not comply with the sewer-use by-law. However, while the treatment principles outlined will find general application at all tanneries, the exact system which should be employed in a given case will depend on the specific circumstances.

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Now, excellent as these treatment steps are, there remains the fact that much of the waste produced is unnecessary, since recycle and recovery of both water and processing chemicals is possible. Unhairing solution, tanning solution (and perhaps the bate) may be held for re-use, the correct reagent concentrations being maintained by suitable additions. All that would be required to effect such re-use would be holding tanks for the solutions and associated piping and pumping equipment. In the case of the unhairing solution, however, screening and sedimentation might be required.

If re-use is simple and acceptable from a quality control viewpoint, it may be asked why it has not found favour with the tanning industry in general. The answer lies partly in costs, but much more in the antiquated wastewater handling techniques employed at most tanneries. Many plants are old and to re-arrange the processing and drainage systems to accommodate the latest wastewater treatment technology would be a major undertaking. Not to be underestimated also is the strength of tradition which resists and retards change. However, rather than introduce a mass of details on what can be done to reduce the quantity and upgrade the quality of tannery waste-water, it is suggested that the literature be consulted for further information. A great deal has been written

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on this subject and appended therefore, is a list of a few references which may be useful.

To summarise briefly, tannery wastewater will normally require treatment before discharge into a sanitary sewer system. However, acceptable treatment is relatively simple and need not be excessively costly especially if re-use of solutions is practised. The major treatment steps which may be required include screening, sedimentation, coagulation, equalisation, pH control, clarification, biochemical oxidation of organic material and oxidation of sulphide.

MEAT PACKING AND RENDERING

INTRODUCTION

Animals have provided men with a source of food since the earliest recorded times. In Canada the first European settlers relied upon wild animals for meat supplies. As permanent settlements became established domestic livestock were imported to ensure an adequate year-round supply. In the 17th and 18th centuries meat was preserved by packing it in salt in wooden barrels, hence the term "meat packing" originated. This term has continued to be used but does not now completely describe today's multi-million dollar industry. Meat packing is Canada's largest food industry with value of shipments approximately $1.8 billion, ranking it third following the motor vehicle and pulp and paper industries.

In Canada today the approximate annual per capita meat consumption is: beef 87 lbs, pork 63 lbs, poultry 45 lbs, veal, lamb & mutton 3.5 lbs, fancy meats 3.4 lbs, canned meats 4.7 lbs. Canada ranks #6 in world meat consumption per capita. This consumption represents approximately the following yearly slaughtering: (1971 Statistics) cattle 3.29 million, hogs 11.6 million, calves 0.76 million, chickens and turkeys 340 million.

For convenience of discussion we can divide our

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topic into three distinct areas, Meat Packing, Poultry Processing and Rendering.

Companies engaged in meat packing vary widely in such areas as economic scale, general type of operation and degree of government supervision. 80% of Canada's meat supply is processed in 300 federally inspected plants while another 1,000 smaller plants operate under provincial or local inspection systems to produce the remaining 20%. A major meat plant will slaughter all species of meat animals and process the carcase into fresh meat, cured and smoked meats, cooked meats and sausage products and canned meats. Some of these major plants are also engaged in processing edible and inedible by-products. This latter processing includes lard, leather, soap and animal feed production. Many of the smaller plants carry out only slaughtering and processing of the carcase into meat quarters or finished meat cuts for individual and retail requirements.

MEAT PACKING

Processes, Sources and Characteristics of Wastewaters

In large modern slaughterhouses (abattoirs) killing and subsequent processing is a production line operation. Workers are allocated to a specific operation at stations

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on the production line.

Killing is carried out in one of several ways depending on the type of animal involved. Cattle are usually stunned with a blow from a steel ball fired by a 2,000 psi air pressure device or are shot directly with a small calibre cartridge. Hogs are either inactivated in a carbon dioxide atmosphere or are shot with a cartridge. Following any of the above the jugular vein of the animal is cut to permit rapid free bleeding. This blood is the highest potential source of wastewater pollution loadings and should be treated accordingly. Large slaughterhouses usually collect the blood and either process it further for by-products or arrange for collection by contract renderers. The majority of an animal's blood is drainable and sufficient time for maximum drainage should be permitted.

On a beef production line the animals are hung on a conveyor by a hind leg. The head is removed first together with the lower part of the legs. Next the abdomen is opened and the whole contents removed. This removal includes stomach, heart, liver, kidneys and intestines, the combined weight of these organs being approximately 80-90 lbs. The edible organs are separated and stomach

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and intestines directed to separate disposal. As the carcase progresses the hide is stripped (peels like a banana) and fat and other minor solid parts are cut away. Hogs are dehaired by immersing the carcase in hot water and mechanically vibrating the skin. The small trimmings are usually collected for edible rendering. The carcase is now washed thoroughly in a closed power spray washer. If the carcase is destined for the retail meat trade it is shrouded and cooled rapidly ready for dispatch in refrigerated transportation.

All of the above operations take place on the 'killing floor' and this area is usually segregated from other processes. The major waste loadings arise from blood as it continues to drain from the animals and is washed at different stages. Large quantities of small solid meat and fat particles also find their way into the wastewater flows. This total flow should be pre-treated. Screening through rotating or vibrating screens can be effective in removing the majority of the solid particles.

In the packinghouse further processing is carried out, e.g. cooking, curing, smoking and pickling. Some of the operations carried out, in addition to those

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concerning processing of meat cuts, are: manufacture of sausage and canning of meat, cleaning of intestines for casings, separation of intestine fat for oleo preparation, etc. From all of these operations soluble organic materials and small fat and meat particles gain access to wash water. This waste washwater should be screened to remove the maximum possible amount of solids. If tripe processing is carried out, the content of the animals stomach (paunch manure) must be disposed of. This material is usually wet flushed away and screened. The screeningscan be hauled away for land disposal. All other meat and fat screenings are collected and usually directed to rendering.

Treatment of Wastewaters

If the slaughterhouse or packinghouse is located in a municipality serviced by a sewage treatment plant the wastewaters, after appropriate pre-treatment, are usually acceptable at the sewage treatment plant. The waste loadings contributed by the plants will vary with the size of operation involved and the degree of pre-treatment given prior to discharge to the sanitary sewer. Some municipalities may charge the industry for waste treatment.

If the plant is not located with access to a sewage treatment plant it must provide its own waste treatment. Many small custom slaughterhouses are located in rural areas. These plants may kill from one or two animals per week up to several animals per day. The usual treatment system for this size operation is blood collection, dry solids clean-up and wastewater discharge to a septic tank and tile-field system. Our experience of this type of system in Ontario has shown that satisfactory treatment can be obtained if the tank and tile-field are sized and installed correctly and the water flow is limited to the hydraulic capacity of the tile-field. Blood and solids are either collected by a renderer or, often, buried on plant property.

The large slaughterhouses and packing plants operating their own waste treatment facilities invariably choose biological treatment. The wastes are readily amenable to biological degradation. Many different types of systems are chosen, anaerobic and aerobic stabilization lagoons, facultative aerated lagoons or activated sludge (usually extended aeration modification).

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TABLE A

UNIT PACKINGHOUSE LOSSES

(pounds per 1,000 pounds of live weight)

TYPE	BOD	Suspended Solids	Nitrogen	Grease
Hogs	18.0	12.0	2.67	0.90
DO	15.0	9.1	1.29	2.30
Mixed	12.7	4.6	2.02	1.44
Hogs	13.1	9.8	1.25	2.83
Cattle	20.8	14.8	2.24	.68
DO	15.7	14.8	2.01	1.79
DO	10.5	10.0	1.02	1.00
Mixed	19.7	9.4	2.59	.60
Hogs	9.8	7.2	1.46	.27
Mixed	16.7	15.0	2.18	2.00
Cattle	10.0	11.0	1.08	.55
Mixed	14.7	13.2	1.70	1.50
DO	6.5	6.2	.79	.50
DO	19.2	11.2	2.10	2.10
DO	8.9	10.8	.89	-
DO	21.6	21.7	1.82	6.00
AVERAGE	14.6	12.0	1.70	1.63

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POULTRY

Poultry Processing

In recent years, through the use of mass production techniques, the poultry industry has grown rapidly into a high volume low unit cost operation. In a constant striving for lower production costs, operations are being continually enlarged and consolidated. In Ontario the majority of the major poultry processors are now wholly owned subsidiaries of the large animal feed supply companies. The trend today is to larger processing plants and some Ontario plants can process up to 60,000 chickens per day. In the bigger U.S. plants up to 150,000 chickens per day are processed.

Poultry processing operations are similar to meat packing operations and the associated wastes are also similar. In a typical processing operation the chickens are brought to the plant in cages on open trucks. The birds are manually removed from the cages and hung by their feet to a travelling conveyor. Following stunning, by an electrically charged wire system, the successive operations are: killing, bleeding, scalding, defeathering, picking, singeing, eviscerating, washing, chilling, weighing and packing. The operation is carried out in 'assembly' line fashion with each worker carrying out a specific job. Fig I is a process flow chart.

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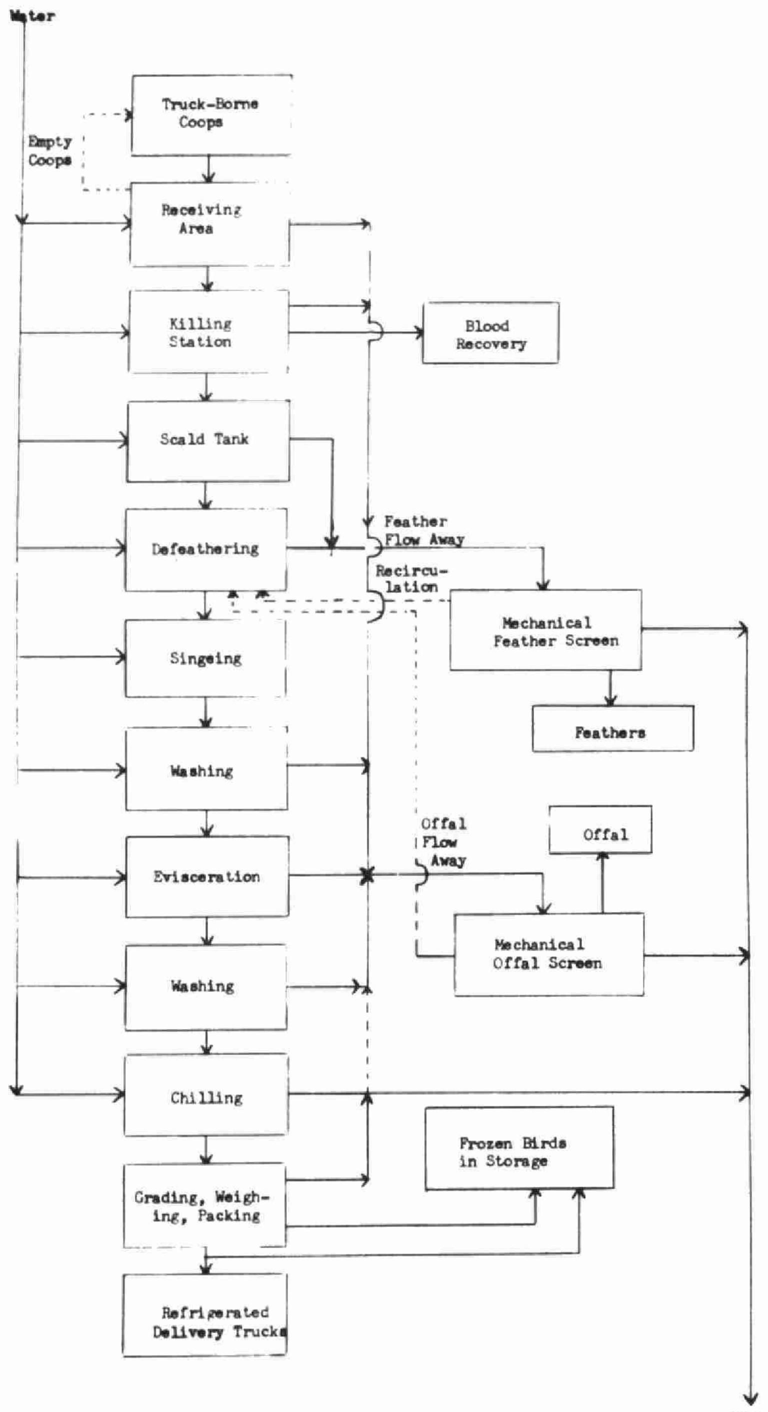
FIGURE I
PROCESS FLOW CHART



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Most large poultry processing plants operate on the "flow away" system. In this system the waste materials, feathers, and solids are continuously removed from the originating area by continuously flowing water. The wastes produced may be divided into processing wastes and clean-up wastes. Processing is usually carried out for 8 to 10 hours followed by a clean-up period of several hours.

Sources and Characteristics of Wastes

(1) Killing and bleeding: The jugular vein of the chicken is cut to permit free bleeding, each chicken contains approximately 1/6 of a pint of blood. BOD_5 of blood is 100,000 ppm and it is imperative to collect the maximum volume possible for efficient pollution control. Killing and bleeding should be carried out in a sloped tunnel and the blood collected in suitable containers. Rendering companies will take blood together with offal and feathers for conversion into inedible oils, fats and animal feed.

(2) Scalding: This is carried out to assist defeathering. The hot water continuously overflows and contains appreciable quantities of blood and feathers.

(3) Defeathering: Feathers are removed mechanically

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in counter-rotating steel drums with mounted rubber "fingers". The feathers are flushed away continuously and should be collected by suitable screening. Water from this operation contains the small 'pin' feathers passing the screens and high concentrations of organic pollutants.

(4) Cutting and Evisceration: This is carried out in an area strictly segregated from previous operations. At this point the lower leg portion is removed followed by removal of the viscera. Federal or Provincial inspection is critical at this point and diseased birds are rejected. Inedible viscera are continuously flushed away. The birds are thoroughly washed inside and out before leaving this area. Flow-away water contains a high concentration of large and small solids and soluble organic material.

Screening should be carried out on the flow-away water from the above operations to remove suspended solids. Many types of screen are in use for this purpose. Both the vibrating rotary type screen and the rotating drum screen are capable of doing satisfactory screening on this wastewater stream.

(5) Chilling and Packing: The processed poultry

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now moves to the chilling stage where body heat is removed as quickly as possible to maintain flavour and storage life. Chilling is carried out by immersing the birds in successively colder water baths which overflow continuously. With efficient operation of the chill system eviscerated poultry can be quick-chilled to around $35^{\circ}F$ in 25 to 30 minutes. At this point the majority of the poultry is packed in ice in suitable insulated paper box containers and shipped in refrigerated trucks. If the poultry is to be frozen it is suitably wrapped and fast frozen. Before shipping all poultry is weighed and graded.

The wastewater from these operations is usually of low BOD_5 concentration and contains only small quantities of suspended solids. This wastewater need not be routed through the screens associated with evisceration.

Waste Treatment

A plant processing 20,000 chickens per day has a population equivalent of 5,000; i.e. the waste loadings from the plant would equal the sewered wastes from a town of 5,000 population. An Ontario-wide survey indicated that the average waste loading from poultry processing plants is approximately 29 lbs. BOD_5 per 1,000 birds processed. Water consumption varies between

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5 and 10 gallons per bird.

The majority of poultry processing plants use flow-away wastewater systems. If the plant is located in a municipality with sewage treatment plant service it is usual for the plant to carry out pre-treatment of the wastewaters and then discharge to the sanitary sewer leading to the sewage treatment plant. The municipality will often charge the company for this service, but this means of disposal, where available, is certainly more economic than if the company were to treat the wastes completely in their own specially constructed facilities. The pre-treatment facilities should include blood collection, feather screening, offal and viscera screening and possible grease separation. Blood collection is the most important pollution reduction aspect. The overall waste loadings from a poultry processing plant can be reduced up to 40% by efficient collection.

If the plant is not located in a municipality serviced by a sewage treatment plant, independent treatment facilities are required. This means additional treatment beyond the in-plant, pre-treatment. Efficient pre-treatment is equally important since any waste loading reductions achieved reflect directly upon final treatment capital and operating costs.

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Final treatment for poultry plant wastewaters is usually biological. The wastes involved are readily amenable to biodegradation and, so far, the economics of this method have proved better than other alternatives. The type of biological treatment most favoured in Ontario is the extended aeration modification of the activated sludge process. This type of treatment is favoured for several reasons.

(1) shock loadings do not affect the process as seriously as they do conventional activated sludge plant.

(2) better operational flexibility is obtained.

(3) very little excess activated sludge is produced and hence sludge disposal is minimized.

(4) operator attendance is reduced and process operation is simplified.

Air is usually supplied to the biological treatment unit by mechanical surface aerators. After clarification of the effluent, chlorination is required prior to discharge to a receiving watercourse.

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TABLE B

COMPOSITION OF COMBINED POULTRY PLANT WASTES

	RANGE
Five-day BOD,mg/l	150 - 2,400
COD,mg/l	200 - 3,200
Suspended Solids,mg/l	100 - 1,500
Dissolved solids, mg/l	200 - 2,000
Volatile Solids, mg/l	250 - 2,700
Total Solids, mg/l	350 - 3,200
Suspended Solids, % of total solids	20 - 50
Volatile Solids, % of total solids	65 - 85
Settleable Solids, mg/l	1 - 20
Total Alkalinity, mg/l	40 - 350
Total Nitrogen, mg/l	15 - 300
pH	6.5 - 9.0

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RENDERING

The first recognition of this industry should be its valuable contribution to overall waste control. This contribution is made by converting waste materials from the meat packing and poultry processing industries into valuable by-products. The material produced is high in protein and sells for up to $200 per ton. Since utilization and recycle of waste materials is essential in future pollution control, this industry must be a pioneer in the field.

Large meat packing plants may have an integral rendering operation to handle their own waste materials. Small plants usually have contracts with plants who specialize only in process rendering.

There are two types of rendering, edible and inedible, the latter term is applicable only to human consumption. For edible rendering the raw material must be classified as edible waste and the processing must be carried out under stringent hygenic conditions. Inedible rendering can accept those wastes classified as not suitable for human consumption and includes such waste material as animal and poultry viscera, blood, bones, feathers, skin and fat.

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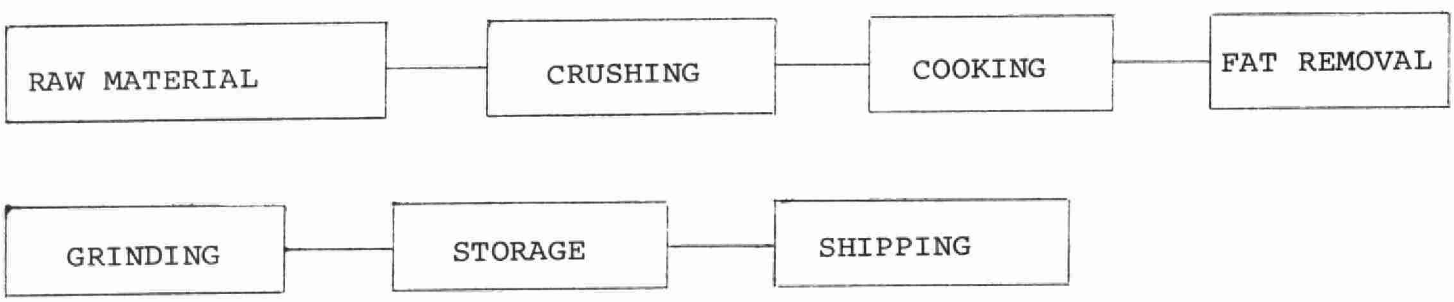
Wet rendering was formerly widely practised; this method involved cooking the waste in hot water tanks and skimming off the liberated fat and grease. The method is not widely used now and may be confined to some hog renderings for production of lard. The residue from any wet rendering plus all the other waste materials is normally dry rendered. This rendering is carried out by heating the materials to remove moisture and grinding the resultant material to produce a granular meal. The product meal can also be further dried or squeezed for removal of fat.

Fig. II

FLOW DIAGRAM



There are two rendering systems using batch cookers and continuous cookers. In both types of cooker the material is heated to 250-260°F by indirect steam. At these temperatures the moisture in the material, normally 50-70%, is driven off and the complex proteins are broken down. Fat is also released and separates out as

'tallow'. The tallow is allowed to drain off and the cooked material is fed into a filter for additional fat removal. Both fat and meal are subjected to further processes before storing for eventual sale.

Wastewater Sources

The major wastewater source is the water contained in the raw material. Since this may constitute as much as 50-60% of the raw material the volume is considerable. A large rendering plant may process up to 2,000 tons of waste material per week. This would result in approximately $\frac{2{,}000 \text{ tons} \times 2{,}000 \times 60 \text{ lbs.}}{10 \times 100} = 240{,}000$ gallons/week of water expelled from the raw material. The water is driven off as steam during cooking and contains steam-distilled organic compounds including amines, aldehydes, mercaptans, fatty acids and sulphides. These gases and vapours must be condensed (odour control) and condensation is usually accomplished by either surface condensors or barometric condensors. The surface condensors are often cooled by water from a closed circuit cooling system. The volume of wastewater from surface condensors is essentially that volume contained in the raw material. In barometric condensors the cooling and condensing is achieved with direct contact of water. Thus the volume of condensate from the raw

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material is mixed with the barometric cooling water. Waste strength of these condensates can range up to 10,000 parts per million BOD_5.

The second major source of wastewater arises from floor, equipment and truck washings, spills and other minor processes where water is used. This wastewater usually contains high concentrations of suspended solids, emulsified fats and soluble organics. The volume will be dependent upon the size of the rendering plant and the BOD_5 can range from 1,000 to 2,000 ppm.

If the rendering plant or operation is located in a municipality with a sewage treatment plant the wastewaters, following pre-treatment, would normally be discharged to the sanitary sewer. The minimum treatment would be screening and the maximum, screening and grease separation. Grease separation is effected usually by a conventional grease separator or less frequently in a dissolved air flotation unit. A rendering operation should ensure, by good housekeeping practices that the minimum quantity of solids and grease reaches the final wastewater discharge. The incentive for this is twofold; dissolved solids, emulsified fats and soluble organic material in the wastewaters are a

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'product loss' and also are the pollutant materials that exert a high oxygen demand. When a rendering plant is not serviced by a municipality waste treatment beyond the in-plant pre-treatment is required. One large Ontario rendering company has successfully established an almost total recycle operation where the wastewaters are stabilized in large ponds and eventually recycled as barometric condenser water. Another large company successfully spray irrigates all its wastewaters onto suitable adjacent land.

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BREWERIES

DISTILLERIES

and

WINERIES

The title of this section of the course could well have been the fermentation industry, and indeed this is the normal classification used in textbooks dealing with industrial processes and wastes. However, in Ontario, the fermentation industry consists essentially of the breweries, distilleries and wineries since there are only two other plants using fermentation to produce auromycin, declomycin and vinegar. There are other industrial processes that might, in the broadest of terms, be classed as fermentation processes and the ones that come to mind are the making of buttermilk and yogurt in dairy operations and digester operations at sewage treatment plants. However, in all cases these latter processes use strains of bacteria to effect the desired conversions and not yeast as do the true fermentation industries.

An industry closely associated with the alcoholic beverage industry, especially the breweries, is the malting industry which converts barley to malt and in doing so generates potent wastes.

Although breweries, distilleries and wineries are related in many ways, there are significant differences that we will discuss later. One common factor in all

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three, and indeed with most industries, is the presence of a boiler house or steam plant. This can present two problems; water treatment for boiler water make-up which can generate wastes, and the possibility for fuel spills if oil is the fuel being used. These topics are dealt with elsewhere in the course.

Production of alcoholic beverages has been practised for centuries and in spite of this, the process is still as much art as it is science. For this reason the producers are reluctant to change their methods and procedures. Certainly there have been refinements and increased recovery of by-products which has lessened waste loadings, but the basic operations have changed very little. This indicates that any "break-throughs" in process modifications to reduce waste loadings or in the handling of wastes are remote.

With the exception of two distilleries and one winery, this industry presently discharges its wastes into municipal sanitary sewer systems. This, in our opinion, offers several significant advantages. It reduces the number but results in larger sewage treatment plants where the economy of scale should provide an over-all economic saving. It also insures adequate

operation of the treatment facilities because the municipal sewage treatment plant staff have one responsibility, the operation of the plant, whereas the responsibility for a private industrial waste treatment plant is often delegated to an employee who has production responsibilities which have priority over the waste treatment plant.

In summing up this general discussion, we are dealing with relatively large plants which have significant waste loadings already being discharged to municipal systems, and an industry where significant process changes are unlikely.

Thus, the responsibilities of the regulatory agencies are to ensure that individual waste streams are directed to the appropriate sewer (clean water to storm sewers and contaminated wastes to sanitary systems), to ensure that adequate protection against accidental spills and losses are taken, and to monitor the waste to ensure that sewer-use by-laws are being met or to calculate loading for the imposition of a surcharge for over-strength wastes. It is only by means of this last item that the maximization of by-product recovery and in-plant reductions in waste loadings can be effected.

Because the minimizing of waste loadings from these industries depends on how individual waste streams are handled, the remainder of this discussion will concentrate on processes and sources of wastes.

It is hoped that the information provided in the following sections will assist you in dealing with an existing plant and also to help you determine the impact of a new plant that may locate in your municipality.

BREWERIES

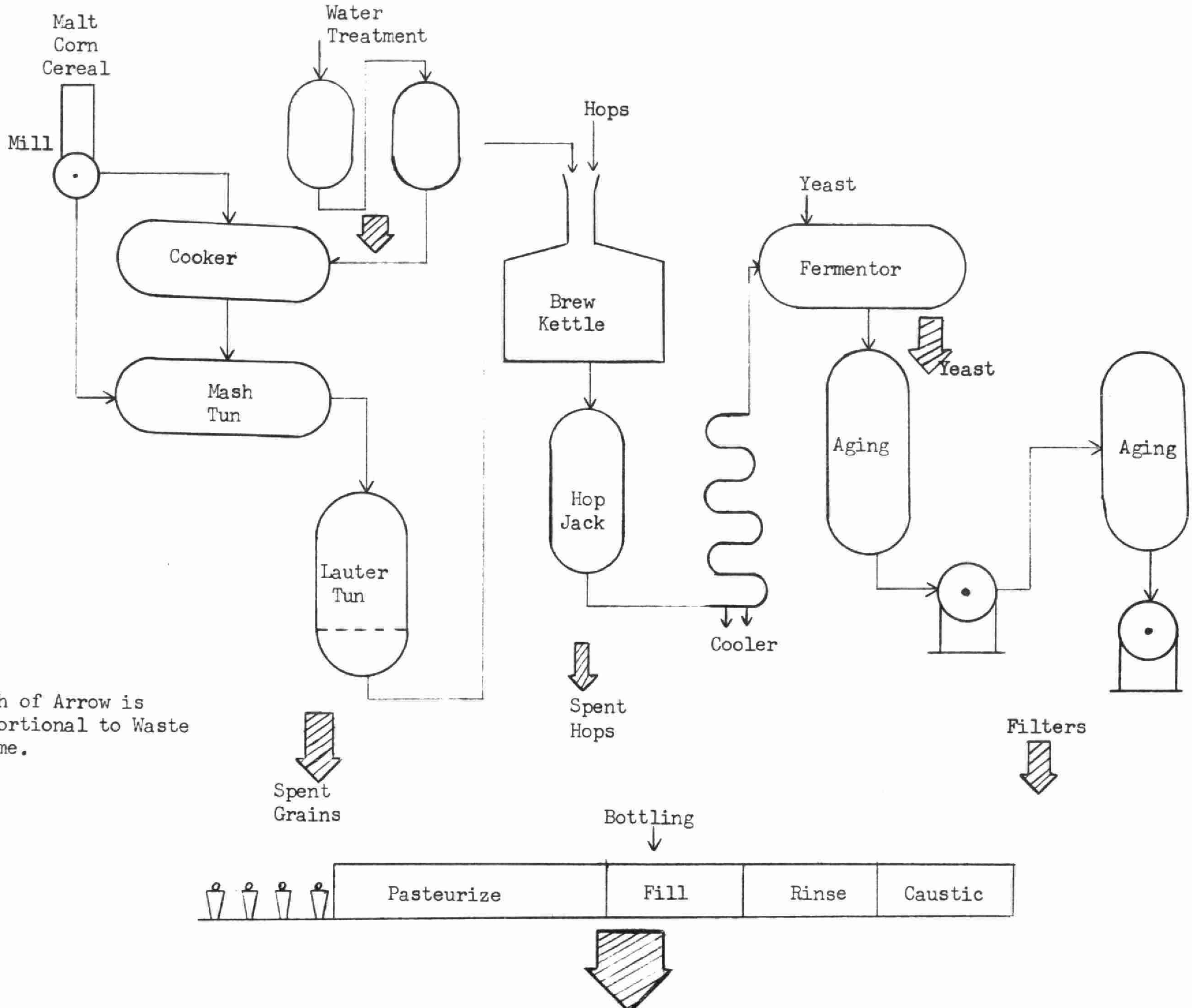
The brewing industry is concentrated in Metropolitan Toronto but plants are located in London, Waterloo, and Barrie, while in Northern Ontario, there are plants in Thunder Bay, Sault Ste. Marie, Sudbury and Timmins. The industry, while expanding in production levels and consolidating production into larger plants is stable in other respects. In recent years only 2 companies have ceased production, Beck's in North Western Ontario and Peller's in Hamilton. Similarily, in recent years only three companies, new to Ontario, have talked of establishing breweries but none have yet appeared.

Processes and Sources of Wastes

Figure I represents a simplified flow sheet for a brewery.

FIGURE I

BREWERY



Note: Width of Arrow is Proportional to Waste Volume.

(1) Water Treatment

To start at the beginning, in the upper left of the flow sheet, Figure I, a water treatment system is shown. Because the final product, beer, is nearly all water, and the product is not distilled, the quality of the water used is extremely important. This importance is carried through into the advertising campaigns of breweries where Hemlock Lake or pure spring water is emphasized. Depending on the water supply the water treatment can vary from dechlorination by carbon filters to more elaborate systems, the most common being de-ionization. De-ionization is a 2-stage ion exchange process, similar to household softeners, and the first major waste stream originates here. When the unit is regenerated strong acid usually sulphuric, and strong caustic are used. The regeneration efficiency is about 50%, thus half of the acid and caustic used ends up as wastes. If both units were regenerated at the same time, the resulting acid and caustic wastes would neutralize each other. However, due to the regeneration cycle this does not happen and the resulting wastes have a pH that varies from 2 to 12 in a period of 1/2 hour. These wastes must be treated. Retaining the strong wastes for mixing and mutual neutralization is one approach, but additional caustic is usually needed to ensure adequate pH control.

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(2) Brew House

The first part of the process consisting of the mill, cooker and mash tub is to form a solution from the components in the malt and grains or cereals, and to effect an enzyme conversion making the solution amenable to fermentation.

Everything is then transferred from unit to unit until it reaches the lauter tun. Here, due to a false bottom or screen, the solution (wort) is separated from the spent grains. The spent grains are a valuable by-product, and are sold as cattle feed. In spite of this by-product recovery, this area is a major source of waste because the liquid draining from the spent grains has an extremely high BOD, as high as 25,000 ppm. On top of this some breweries dry or partially dry the grains, sewering the removed moisture, thus increasing the sewer loading. Spraying of the spent grains (displacing the wort with fresh water) improves the brewery's recovery of wort and also reduces the wastes produced in this area.

The wort and hops are then added to the brew kettle being discharged through the hop jack after brewing. The hop jack acts like a filter, as did the lauter tun, and separates the hops for trucking away to land fill or animal feed.

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(3) Fermenting

Finally the wort is ready for fermentation. It is cooled, added to the fermenters, and the yeast is introduced. This can be and usually is the largest source of BOD from the brewery because during fermentation excess yeast is formed. Most yeast is sewered directly from the fermenters. However, the remaining processes, aging, storing and filtering are to ensure that the final product is crystal clear. Thus, yeast and other protein material are waste materials from this section of the process, being discharged as sludge from the filters or sludge washed from storage tanks.

(4) Bottling

Bottling is a significant waste source. From 1/2 to 3/4 of the water used in a brewery can be discharged as waste from the bottling operation. Bottles returned to the brewery are cleaned inside and out with caustic, rinsed, filled, sprayed with hot water to pasteurize them then sprayed with cold water to complete pasteurization and cool the bottles. The wastes can have a high pH but the accepted practice is to recycle the caustic solutions through a screen to remove labels, cigarette butts, etc., resulting in a batch discharge that must be adequately handled.

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(7) Variability

One final point, brewery wastes are extremely variable. With the exception of the bottling machine, all processes are batch operations resulting in batch discharges of wastes. In a very small operation one batch per day may pass through the brew house, fermentation lasts several days and aging several weeks. Thus none or several units may be emptied and cleaned out on any particular day. Production itself is variable depending on the season. In addition there is a weekly variation. On Monday, everything in the brewery is clean and ready to go. By Friday, the normal shutdown day, accumulations and carry-over of washing operations have increased the daily loadings. These variations have been reported to double the daily loadings on days later in the week as compared to Monday, a start-up day.

Expected Waste Loadings

Having tried to impress upon you the variability of brewery wastes, it is hoped that by quoting numbers in this section, the importance of the variability of the waste characteristics will not be lessened.

The **following** values must be taken as guidelines because of the variability of the wastes and also because of the problems in determining what the actual loadings

are.

To give an order of magnitude to the size of breweries, a very small operation would produce 1 batch (brew) of 2,500 gallons per day or 20,000 barrels per year while the largest would approach 1,000,000 barrels per year.

The following table gives average values for the Ontario breweries. These numbers were the result of a survey a few years ago, and were based on the best information that was available. The values are calculated per barrel of beer (approximately 25 gallons):

Waste Flow	300 gallons	
BOD	2.7 pounds	900 ppm
Susp. Solids	1.8 pounds	600 ppm

These are generally within the range of published data.

<u>Waste Control</u>

One approach to dealing with wastes from a brewery is to consider the following areas:

(1) treatment of wastes that must be controlled

(2) reduction in organic strength

(3) reduction in hydraulic loading

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Treatment of wastes that must be controlled involves pH control for water treatment wastes, caustic boil-out solutions used for clean-ups in the brew house, and soak solutions and caustic rinses in the bottling area. No matter what method of final disposal is used, pH control of these wastes must be effected.

Reduction of organic loading includes a review of the spent grain and hops operations to ensure that these are efficient; the promotion of by-product recovery, especially yeast; the removal of filter cakes in the dry form; and the continual battle to reduce and eliminate accidental losses from operational errors and leaking equipment.

In considering the reduction in waste flow it must be remembered that this will not affect the organic loading, and will in fact increase the concentration of waste constituents. To be considered here are segregation of uncontaminated flows for discharge to the storm sewer. This includes the neutralized water treatment wastes, cooling water from the wort cooler, fermenters, compressors and refrigeration systems. In addition some segregation on the bottling machine should be possible. After the bottles are filled, the initial

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spray could be collected as contaminated wastes with the subsequent hot and cold sprays segregated for discharge to the storm sewer.

In the preceeding paragraph, reduction of hydraulic loading has been interpreted as reduction in the volume of contaminated wastes that require further treatment. True reduction in hydraulic loading can only be effected by using less water.

Methods of Disposal

All breweries in the Province presently discharge their wastes to municipal sanitary sewer systesm.

A few years ago, one Company operated a private disposal system. Because the plant was small and in a rural area, land was available and the Company operated a spray irrigation system using a holding lagoon to retain wastes during the winter when spraying was not possible. When the Company built a new brewery in another municipality, a biological pretreatment system was installed in order to have the wastes accepted into the municipal system. This is the only treatment system in the Province treating brewery wastes exclusively.

At the present time biological treatment in one of its forms, lagoon, aerated lagoon, conventional

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activated sludge or trickling filter appears to be the only practicable method of treating brewery wastes in which a substantial reduction in organic strength can be achieved. While one Company did operate a non-effluent treatment system, spray irrigation, few of the remaining breweries are in locations where enough land would be available at a reasonable cost to make this an economic alternative.

To the best of our knowledge none of the breweries is causing problems that cannot be handled by the municipal plant operators. However, most breweries have been discharging wastes to the municipal systems for so long that the systems have likely been expanded to accommodate them, and operators have learned to cope with any problems that arise.

With the exception of one municipality, no surcharges are being applied for overstrength wastes. Even with the growing trend, and hopefully a continuing trend, to control industrial wastes in municipal systems and to apply surcharges for over-strength wastes, the breweries would likely continue as they are and pay the surcharge. In many respects this is the preferred approach for the expertise of brewery personnel is in making beer while that of sewage plant

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personnel is in treating sewage.

DISTILLERIES

In considering distilleries there are many similarities with breweries but the approach to by-product recovery is quite different.

Plants in Ontario are located in Windsor, Amherstburg, Waterloo, Bramalea, Toronto, Corbyville, and Collingwood and a different type of distillery, a brandy distillery, is just starting up in the Niagara Peninsula.

The size of these plants varies from one using 1,000 bushels per day of grain (mainly corn) and 150,000 gpd of water, to one using in excess of 10,000 bushels per day and some 8 mgd of water.

Processes

Looking at the simplified flow sheet for a conventional distillery, Figure II, the first thing to be noted is that there is not an elaborate water treatment system at the beginning. While water quality at this point is important it is not as critical as at a brewery since the product will be distilled.

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The initial part of the process, the mill, cooker and drop tun serve the same purpose as the first steps in a brewery; to put the material into solution and effect an enzyme conversion so that the yeast can produce alcohol. Here is a major difference with respect to brewery operations. The spent grains are not separated. The entire mash is cooled and added to the fermenters with the yeast. Following fermentation the entire contents are pumped to the beer still where the alcohol and volatile components are distilled off and the remainder, including the spent grains, drops out at the bottom as "slop". The overhead material is further distilled to separate the product which is aged, blended, cut and bottled. In a distillery a water treatment system is needed, at the end of the process. It is usually a demineralizer to produce the good quality water required for cutting or diluting the final product.

Bottling is significantly different from that carried out at a brewery. It is a dry operation since the bottles used are new, not washed, and the filling operation is closely controlled.

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Sources of Wastes

(1) Cooking

To indicate the sources of wastes, the first one is relatively minor and originates at the cooker. Cooking is done under pressure and when the cooking cycle is completed the pressure is released and a vacuum pulled on the vessel. This allows the mash to continue boiling while it cools but also releases volatile components and usually a carry-over of solids occurs. If a vacuum pump or condensor is used, a low volume waste is generated but if a barometric condensor is used a large volume of low strength waste results which is difficult to handle.

(2) Distilling

The mash cooler produces a large flow of uncontaminated cooling water; the fermenters also require cooling water; slop from the beer still is further processed leaving the distillation bottoms as a waste. These tails or lutter water can be separated in fractions as industrial solvents, or can be sent to another plant for separation. No matter what the procedure, a sewered waste results.

(3) Water Treatment

Regeneration of the de-ionizer produces acidic and alkaline wastes which must be treated, and depending on the boiler water treatment system further wastes

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are usually generated.

(4) Boil-Outs

The most significant waste loading results from the weekly or twice-weekly boil-out, similar to that in a brewery. Several thousands of gallons of approximately 3 per cent caustic solution are boiled in the process equipment and passed through the process train. This results in a batch waste with a high pH and a large organic content. The BOD loading is usually much greater than the total loading discharged on a normal operating day.

(5) By-Product Recovery

The bottom half of the flow sheet (Figure II) represents the dry house or recovery operation. This is an integral part of a conventional distillery due to the high value of the by-products which are recovered.

Slop has been fed to cattle directly from the beer still, but this generally presents problems. A lot of water must be trucked, and due to the low solids content of the material the cattle do not gain weight without an additional food source. In addition this transfers a distillery waste problem to a cattle manure problem, which may be more difficult to control.

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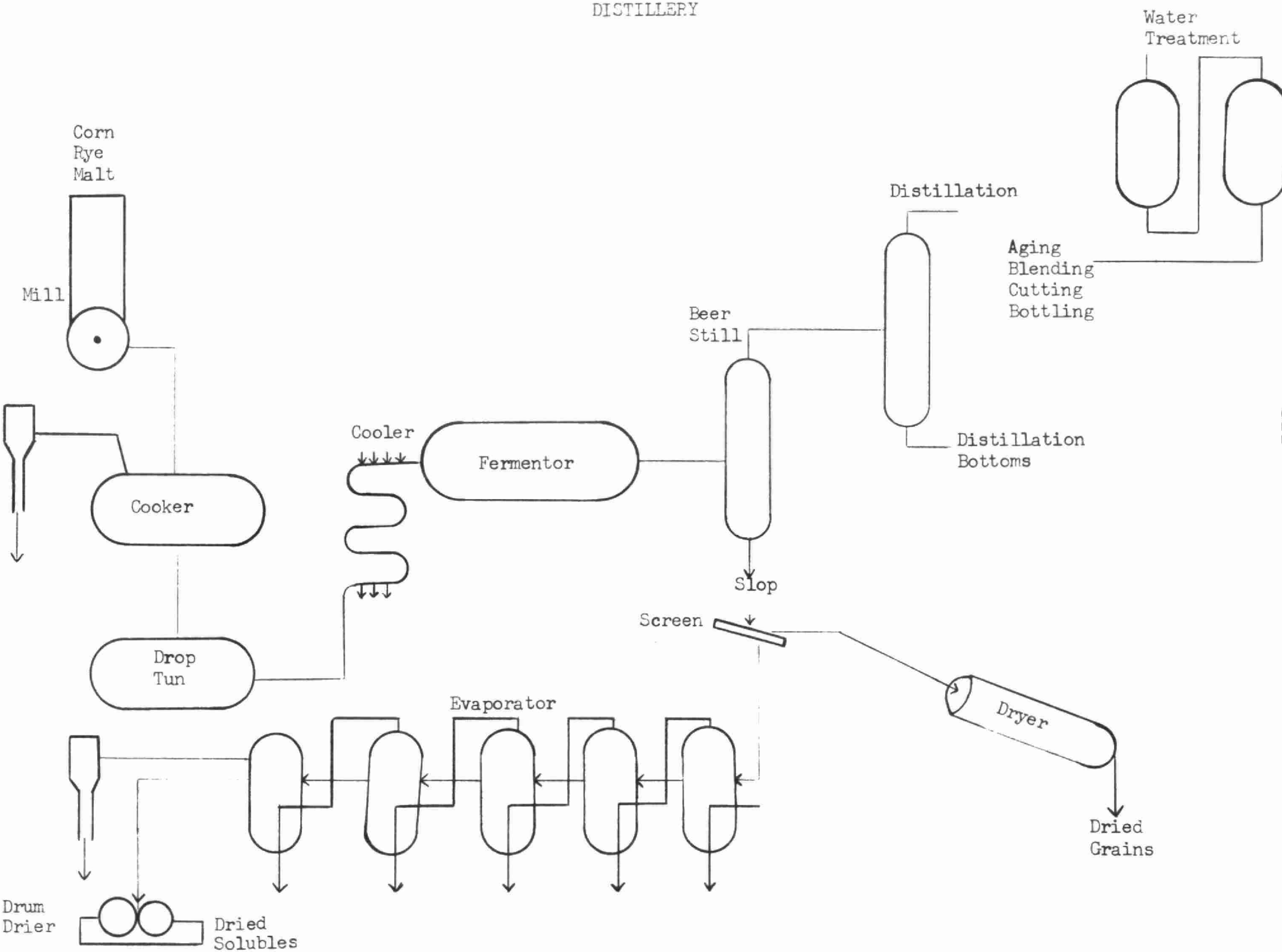
FIGURE II

DISTILLERY



The standard practice is to screen the slop to separate the spent grains for drying in a rotary drier, and pump the liquid to a multiple effect evaporator to be concentrated then dried in a drum drier.

With the exception of the caustic boil-outs, the operation of the evaporator produces the most significant organic waste, and thus this operation will be described.

In a simple evaporator 1 pound of steam will theoretically evaporate 1 pound of water. In a multiple effect evaporator, such as a five effect as shown, 1 pound of steam will evaporate 5 pounds of water. A vacuum is applied to the final effect, and this in turn results in a slightly lower vacuum in each of the preceeding effects. This allows each of the effects from the beginning to operate at a slightly lower temperature. Steam from the boiler heats the first effect, and the condensate can be returned to the boiler. The water evaporated, acutally water and volatile components having a BOD of some 600 ppm, from the first effect condenses in the coil of second effect, and since it is under a vacuum must be pumped out of the heating coil. Similarily water evaporated from the second

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effect condenses in the third effect and so on. The water evaporated from the final effect is collected by the barometric condensor which is used to produce the vacuum on the evaporator.

Thus, the water added to the process through the cooker leaves by means of the evaporator condensates except for the small amount in the distillation tails, a smaller amount in the product, and moisture losses from the driers.

(6) Equipment Leaks and Spills

As in all industries equipment leaks and spills are a major consideration, and in distilleries the dry house area is the most important in this respect because of the high organic content or BOD of the material being handled.

Waste Disposal Practices

Disposal practices of the distilleries in Ontario have been for many years a combination of waste discharges to municipal sanitary sewer systems and to natural watercourses. The following course of events was our approach to those discharging to watercourses, and thus under our direct jurisdiction, but the results apply equally well to plants on municipal systems.

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In the early and mid-1960's a medium size distillery discharged about 1 mgd essentially from the mash cooler but including other distillery cooling waters and distillation bottoms. This waste had a BOD of 20 to 30 ppm. Another 1 mgd was discharged from the dry house including the barometric condensor and the condensates from the multiple effect evaporator. This flow had a BOD in the range of 100 ppm. Caustic boil-out wastes were not controlled and were not likely included in the above figures.

Looking at the process flow sheet, the course to be followed is fairly evident. Contaminated wastes, distillation bottoms, miscellaneous wash water, and the condensates from the middle effects can be segregated for treatment in either a municipal or private treatment system. This was the approach taken. One plant has yet to negotiate with the municipality for acceptance of these wastes, one built a private treatment system and the rest discharge to municipal systems.

The most significant waste, boil-out solution, can be hauled away, neutralized and added to the contaminated wastes for treatment or perhaps bled into the recovery plant.

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To go a step further, uncontaminated cooling water, such as from the mash cooler, can be recycled through cooling towers. The need for treatment of the blow-down from this sytem would depend on the chemicals added to control corrosion and slime growths in the system. Similarly the flow from the barometric condensor in the dry house can be recycled through cooling towers, but this flow also picks up BOD from the final effect on the evaporator and the blow-down would require treatment for BOD removal.

Expected Loadings

While the data we have collected shows fairly high variations between different plants, expected loadings appear to be about 0.3 pounds of BOD per bushel of raw material. Again the waste flow that can be segregated for treatment is extremely variable but 10 gallons per bushel seems reasonable.

Thus a large distillery (10,000 bushels per day) could segregate up to 3,000 pounds of BOD in a flow of 100,000 gallons per day for treatment, and discharge several million gallons per day of cooling water to a storm sewer or natural watercourse.

WINERIES

Having discussed breweries and distilleries, wineries can now be considered very quickly.

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Process and Sources of Wastes

Referring to the simplified flow sheet, Figure III, and considering only grapes, again there is no elaborate water treatment system since there is no added water in the product.

The grapes are tumbled to remove the stalks and foreign material, crushed, pressed then fermented. The remaining operations are clarifying the wine, aging, blending and bottling. As in a distillery, bottling is a dry process.

Wash-up of equipment produces significant wastes. The only operation that could be considered as by-product recovery concerns the lees or sediment left in the bottom of the fermenter. This is trucked to a distillery for recovery of the alcohol which is returned to the winery for fortification or strengthening of some types of wine.

One waste product is the pulp remaining after the juice has been removed. This is discharged from the press or from the fermenter since some wines are fermented "on the skins" or the skins are also added to the fermenters. This pulp is trucked away and usually

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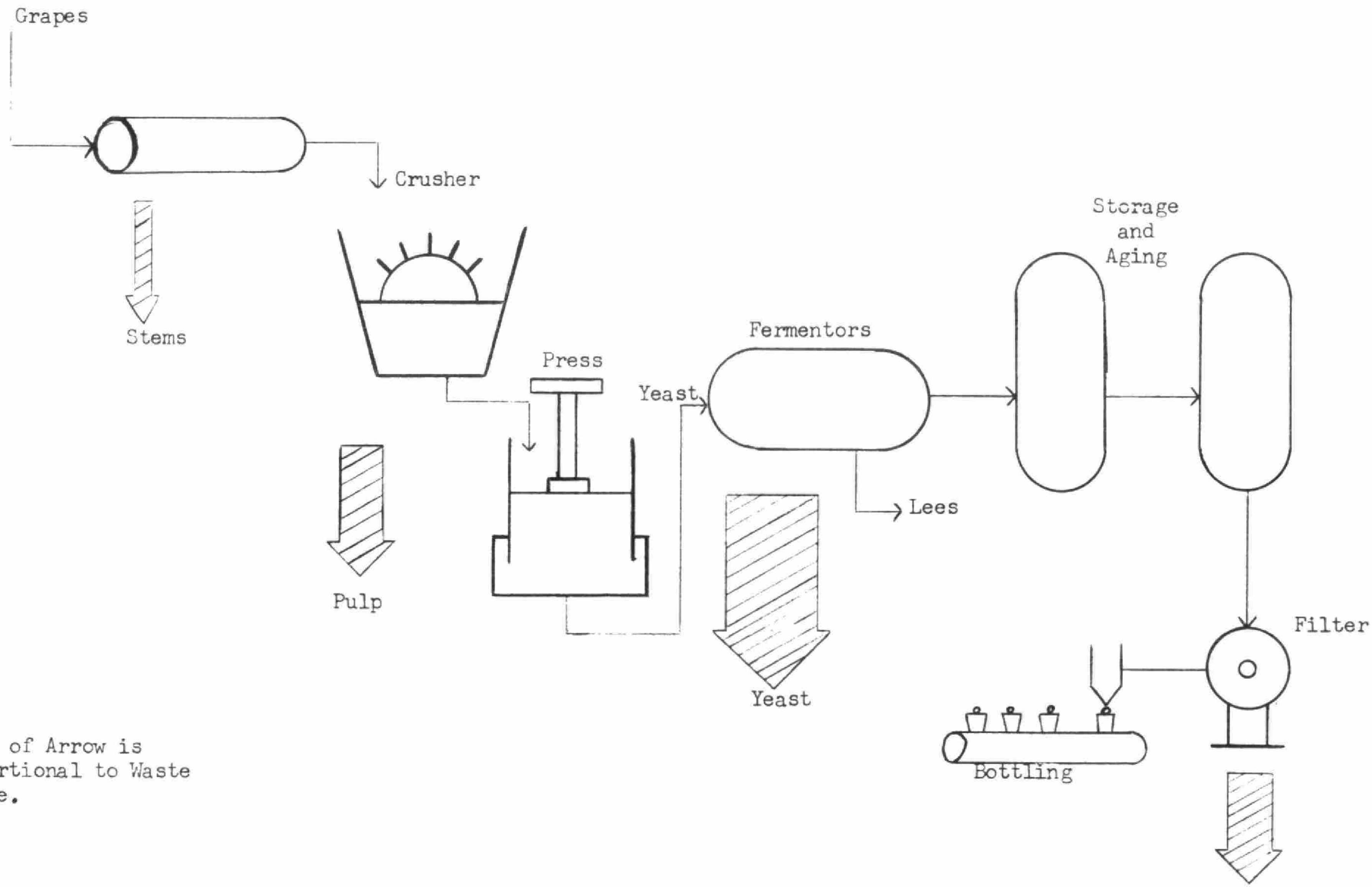
FIGURE III

WINERY



Note: Width of Arrow is
Proportional to Waste
Volume.

ploughed into the ground in the vineyards. Since the rest of the process is essentially to remove solids to leave the wine clear, the sediment is removed either in the form of a filter cake or tank washings. Depending on the design of the filter, the filter cake can be trucked away for disposal or washed down the sewer.

Expected Loadings

To offer an indication to the size of wineries, a small plant would process 50 tons of grapes per day producing some 180 gallons of wine per ton of grapes. Waste loadings should be in the range of 4 pounds of BOD and 1 pound of suspended solids per ton of grapes processed. While the amount of water used, and thus the concentration of the waste components, varies considerably depending on the cooling water systems (recycled or not) and general procedures, a starting point would be to assume 600 gallons per ton of grapes.

Also expected with winery wastes is a low pH, lower than the 5.5 normally quoted in sewer-use by-laws. In spite of this, we have not noted severe corrosion problems, probably because the low pH is due to weak organic acids. If biological treatment is used for BOD removal the organic acids are also removed and pH returns to a near neutral level.

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Seasonal Operation

One consideration with wineries that is not encountered with breweries or distilleries is the seasonal production schedule. Winery processes, as outlined on the flow sheet, take place for approximately 8 weeks in the fall. During the rest of the year waste loadings are much reduced since the process is reduced to blending and bottling. This can lead to problems if municipal sewage systems are used, and in Ontario all except one winery discharge wastes to municipal systems.

The problem can arise in a small municipality where the sewage loading is approaching the design capacity of the municipal treatment plant, and where there is pressure to maintain a reasonable growth in residential development. When this situation arises you have to have a close look at an industry that uses sewage plant capacity for 8 weeks while a new subdivision would use the capacity all year. If sewage plant capacity is reserved for an industry, even for 8 weeks, that capacity is not available for residential development. Further consider that the wastes from a small winery, in terms of BOD, are equivalent to a 200 lot subdivision.

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Waste Reduction

In attempting to reduce waste loadings from a winery, two general concepts are involved.

The first is to put as much of the raw material into the product as possible. This involves the pressing area, and while most winery presses are reasonably efficient, older presses are capable of coating the ceiling and walls of the press room. Apple juice plants are more likely to be a problem in this regard, and a prime suspect would be someone starting up a small juice plant using a second hand press. Another consideration is the efficient and complete draining of tanks and equipment before the wash-up commences. As with most food plants, the products being handled have an extremely high BOD. Thus the prevention of spills and leaking equipment is extremely important.

The second general principle is that the more material that is trucked away for disposal, the less there is to flush to the sewers. This involves efficient removal of the grape pulp and the land disposal of the filter cake. Most, if not all of the filters being used are designed for flushing of the filter cake to the sewers. However, filters designed for dry cake

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disposal are available.

Methods of Treatment

Due to the seasonal nature (8 weeks in fall) and high strength of winery wastes, spray irrigation would appear to be the obvious and most practicable method of waste disposal. However, the Ontario wineries are located in urban areas where the land required for spray irrigation is not available.

With winery wastes, as is the case with breweries and distilleries and also with most food processing wastes, the organic loading or BOD is the main consideration. Thus, biological treatment is still the only practicable treatment method available. Biological treatment can be used to treat winery wastes on their own, not mixed with municipal wastes, and the closest winery with such a system is in New York State, using aerated lagoons followed by polishing ponds to meet the State's trout stream criteria.

As stated previously, all of Ontario's wineries, with one exception, are connected to municipal systems and none have elaborate pretreatment systems. However, none appear to be causing severe problems at municipal sewage treatment plants.

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SUMMARY

The purpose of this presentation is to show that the operations in breweries, distilleries and wineries result in significant wastes, and to give the order of magnitude of the waste loading that may be expected. Investigations of individual plants may result in waste loading data significantly different from data mentioned here. However, by going back to the process and the source of the individual wastes, efforts to effect more efficient waste control can be directed to the areas where significant improvements can be realized.

At the beginning of this presentation it was stated that this industry is reluctant to change its operating procedures. In spite of this we have found the industry co-operative in its approach to waste control. There are several reasons for this. The industry has the money to do what it must do and, while "the art" is still involved in making alcoholic beverages, the plants are run by competent scientific personnel. They are operating processes similar to those at sewage treatment plants, and thus can readily understand the problems that may result if wastes are not adequately controlled. Finally, this industry is one that deals

directly with the public in creating a demand for its products. In order to maintain its position in the market place it guards closely its public image. The industry dislikes adverse publicity of any kind and avoidance of such publicity which might arise over a pollution control problem is strong motivation for maintaining adequate control of wastes.

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VEGETABLE AND FRUIT PROCESSING

INTRODUCTION

There are some 150 establishments in Ontario registered with the Federal Government as plants processing fruits and vegetables and preparing them into a canned commodity. This presentation will cover canning industries only and will exclude such plants that make specialty products such as maraschino cherries, sugared orange peels, raisins, etc.

During the peak operating season, the active canneries in Ontario represent a total labour force in excess of 60,000 people. In general canning is a seasonal operation lasting for approximately six months say from early May through to the first frost, usually at the end of October. The processing at these plants varies continuously and widely fluctuates with the type of produce, market demands, weather conditions, size of crops, etc. Canneries that operate year-round usually produce related food products such as soups, pork and beans, macaroni products, etc., during the off-growing season.

From the waste point of view, the canneries present a somewhat unique problem because they discharge large volumes of strong wastes normally only during the summer months. The volume and nature

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of the wastes varies considerably with each pack and therefore any treatment facilities provided to handle these wastes usually have to be very flexible in order to provide complete treatment. Because canneries produce food for human consumption, they are subject to strict requirements under the various health legislations. As absolute cleanliness is one of the main requirements this necessitates the heavy use of water to keep all utensils, machines, tools, and the product itself clean. Hence, a high volume waste discharge is the prime characteristic of the industry.

Process wastes from the canning industry should not be discharged to a watercourse without treatment as these normally contain high concentrations of suspended solids, as well as soluble organics that can exert a high BOD. These wastes are discharged in the summer during the tourist season when waters are used extensively for recreational purposes. Because of their conspicuous nature these wastes are easily detected and can become a significant public nuisance.

The wastes from a canning industry while they contain high concentrations of organics do not in themselves pose a hazard to public health since they

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are not toxic. The organic nature of the waste is significant when it is considered that during the warmer weather the dissolved oxygen content in a natural body of water is relatively low and the rate of decomposition is relatively high. The effects of an organic discharge to a watercourse become more severe at this time of the year, and therefore, treatment of wastes prior to disposal becomes an absolute necessity.

Under the various government financing schemes more and more sewage plants are being built in smaller communities and municipalities. Many canneries in this area will therefore discharge their wastes to the sanitary sewers for treatment at these plants. Also because of better transportation methods that are now available more canneries are now being built in towns rather than in the country to take advantage of the municipal treatment facilities. The combination of cannery wastes and sanitary wastes makes a suitable feed to biological treatment system providing of course that the two are mixed in a suitable proportion.

PROCESSING

Before proceeding with the type of problems that may be encountered from the indiscriminate discharge of

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canning wastes to the sanitary sewer, it may be best at this stage to cover some of the internal operations associated with the canning of a product. Generally, the harvest arrives by truck directly from the farms for immediate processing since prolonged storage may deteriorate the quality of the product. From the unloading platforms conveyors are used to carry the produce into the plant. If the fruit or vegetable is of a fragile nature, it is normally dumped into a water flume to soften the fall and thereby prevent bruising. This water is usually recirculated and sewered only when it becomes too dirty, normally at the end of the operating day.

Once inside the plant the produce receives a primary wash which may be in the form of a spray rinse or immersion into a running water rinse to remove the mud or grit. In the case of corn, the produce is passed first through a cutter where the husks are removed. Wastes from the primary washing operation are normally low in BOD and high in suspended solids. This is especially the case when root vegetables such as potatoes, carrots, beets, etc., are processed.

After the primary wash the produce goes through

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a number of preparatory stages to bring it to a final state suitable for canning or freezing. A number of process wastes are produced during these stages. The nature of these wastes varies widely depending on the product and the number of operations required.

Pea and string beans require little processing other than washing and classifying. A brisk spray is usually sufficient to wash the produce to remove the loose dirt and cuttings, before centrifuging and screening to grade the product. Large quantities of water are used as a carrying medium to transport peas from one stage to another. In general, when peas and wax beans are processed, high volume of wastes are produced that are relatively low in BOD and suspended solids. In some cases, however, where the distance of transport is great, pumps used to convey the product may crush the produce and thereby release natural juices into the water transportation medium. If this occurs BOD concentrations may increase considerably. Fruits that have pits and cores, i.e. peaches, cherries and pears, have to be opened to remove the inedible material. Prior to this, peaches and pears are passed through a caustic solution to remove the peel and then through a water spray to wash off the adhering chemical. Cherries on the other hand

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are passed immediately to a rotating drum where the pits are removed automatically. Whenever a product is broken during its preparation there is usually a substantial loss of material to the process water resulting in an eventual discharge of strong wastes having high concentrations of BOD and suspended solids.

Potatoes are either peeled mechanically or immersed into caustic solution to remove the outer covering. Rinse waters following this operation contain high concentrations of suspended solids and in the case of lye peeling have a high pH. Potatoes can be canned whole or may be further processed into potato chips or extruded into french fries. To produce chips the potato is thinly sliced and then cooked. French fries are extruded and can be frozen immediately after being washed, or can be pre-cooked and frozen in the partially cooked stage. Potato processing wastes contain high concentrations of BOD (starch), suspended solids, and are normally nutrient deficient. If lye peeling is used, the wastes also exhibit a high pH.

In Ontario tomatoes are usually processed into juice or canned as a whole commodity. In the production

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of juice, the tomatoes are first passed through slashers and then through extruders to separate the solids from the liquid. The pulp is wasted (hopefully to a land disposal site and not to sewer) while the juice is blended, pasteurized and finally canned. Whole tomatoes are prepared by hand on long tables where the core and peels are removed. Cans containing whole tomatoes are topped off with juice and sealed. Deformed or highly bruised tomatoes are rejected and passed on for juice production. Wastes from the tomato processing industry are discoloured, and high in BOD and suspended solids.

The processing of pumpkins and corn produces the strongest waste discharged from the canning industry. In both cases the product is not only broken but also crushed and since there is a prolonged contact of the vegetable with the process water, there is a substantial transfer of material into the water phase. Dewatering of the corn after flotation washing results in the discharge of a very strong waste. The cooking of pumpkins prior to pulping produces an effluent that is extremely potent. Although the processing of the above two vegetables does not produce large volumes of wastes, they are

extremely strong having high concentrations of suspended solids and BOD.

After the cans have been sealed the contents are cooked by placing the cans into a pressure cooker. After cooking the cans are cooled to lower temperature for easier handling. In some cases the cooling water is recirculated or reused in other plant operations, however in most instances it is sewered after a single run. This waste stream is normally uncontaminated and suitable for discharge to a natural watercourse.

Besides canning, following initial preparation, the fruit or vegetable may be frozen. In most cases the vegetable is blanched which involves partial cooking either by a brief immersion into scalding water, subjection to steam heat, or by simply heating the product by setting it on a hot steel belt. After blanching the product is cooled, packaged, and quick frozen ready for distribution. The only wastes produced from the freezing of vegetables would be periodic dumps of blanch water, cooling water from the compressors on the freezing units, and general clean up waters.

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As all these plants produce foods for human consumption it is essential that all operations be clean. The machinery, floors, and utensils are therefore washed at the end of each processing day. The clean up operations require copious amounts of water and last anywhere from three to six hours. During the period, wastes of variable strengths are discharged, being extremely potent at the start and tapering off towards the end of the clean up period. The effluent contains not only organic wastes but also some alkaline cleaning solutions.

As mentioned previously, the wastes from this particular industry fluctuate considerably from pack to pack and in some cases even from day to day when the same product is being processed. The farming aspects have become very scientific in the last decade. Planting of the crop is planned with care to have the product ripen within a few days of a pre-arranged time to correspond to the predicted market demands and the scheduling of the cannery operations. Consequently as all the product is ready for harvesting, more or less at the same time, the cannery must work in a continuous basis to handle the incoming load. Of necessity the operations can be hurried and at times tend to become somewhat sloppy

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from the waste control point of view. On top of this some of the workers in the lines are piece-work employees and consequently it is very difficult to apply in-plant control.

Because of the nature of the industry, it is difficult to provide an accurate relationship between the rates of production and the waste loadings discharged. If the product is cut or broken during the processing and the internal contents are transferred to the wash waters, the plant effluent is usually very potent containing high concentrations of soluble organics that exert a high BOD. On the other hand if the product is only washed, wastes of relatively low BOD are involved.

Significant pollutants in this industry arise from the following operations:

(1) lye peeling
(2) sorting, slicing, cutting, blending
(3) processing
(4) washing
(5) cooling of cans
(6) plant clean-up
(7) box washing

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In general the wastes may be divided into three broad categories: peas and wax-beans processing wastes are high in volume but relatively low in suspended solids concentrations and exhibit a relatively low BOD; peach, carrot, tomato, strawberry, potato, and cherry processing wastes are of intermediate strength and volume; and finally corn and pumpkin processing wastes are low in volume, but very potent containing high concentrations of suspended solids and exhibiting an extremely high BOD. The approximate relationship of the production rate to the expected strength and volume of wastes discharged is presented in Table "A". These figures are based on information obtained during surveys of various canneries throughout the Province carried out by the field staff of this Ministry.

The following figures I to VI show the various flow charts pertaining to the processing of the various products.

MUNICIPAL TREATMENT OF PROCESS WASTES

There are a great number of canneries throughout the Province that discharge their wastes to a sanitary sewer for eventual treatment at a municipal sewage treatment plant. In a broad sense, because of their organic nature, cannery wastes have always been

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TABLE A

TYPICAL CANNING WASTES

PRODUCT	WASTE VOLUME	BOD		SUSPENDED SOLIDS	
	(gal/case*)	(mg/l)	(lbs/case*)	(mg/l)	(lbs/case*)
APPLES	29-46	1,500-5,500	.6-1.3	300-600	.10-.20
CHERRIES	14-46	700-2,100	.16-50	200-600	.05-0.14
PEACHES	51-69	1,200-2,800	.69-1.20	450-750	.24-.34
ASPARAGUS	80	16-100	.01-.07	30-180	.02-.12
BEANS GREEN/WAX	30-51	160-600	.15-.67	60-150	.02-.04
BEETS	31-80	1,600-7,600	1.00-2.00	740-2,220	.50-1.0
CARROTS	36	520-3,000	.11-.67	1800	.40
CORN	28-80	620-6,300	.17-1.50	300-4,000	.07-.95
PEAS	16-86	380-4,700	.27-.63	270-400	.06-.20
POTATOES	-	200-2,900	-	990-1,180	-
PUMPKIN	23-57	1,500-6,880	.72-1.31	785-1,960	.38
TOMATOES	3-114	180-4,000	.11-.17	140-2,000	.06-.13

*A case contains 24 cans of a size in which the produce is most commonly canned.

FIGURE I

SUMMARY FLOWSHEET FOR FRUIT AND VEGETABLE PROCESSING
INITIAL PREPARATION

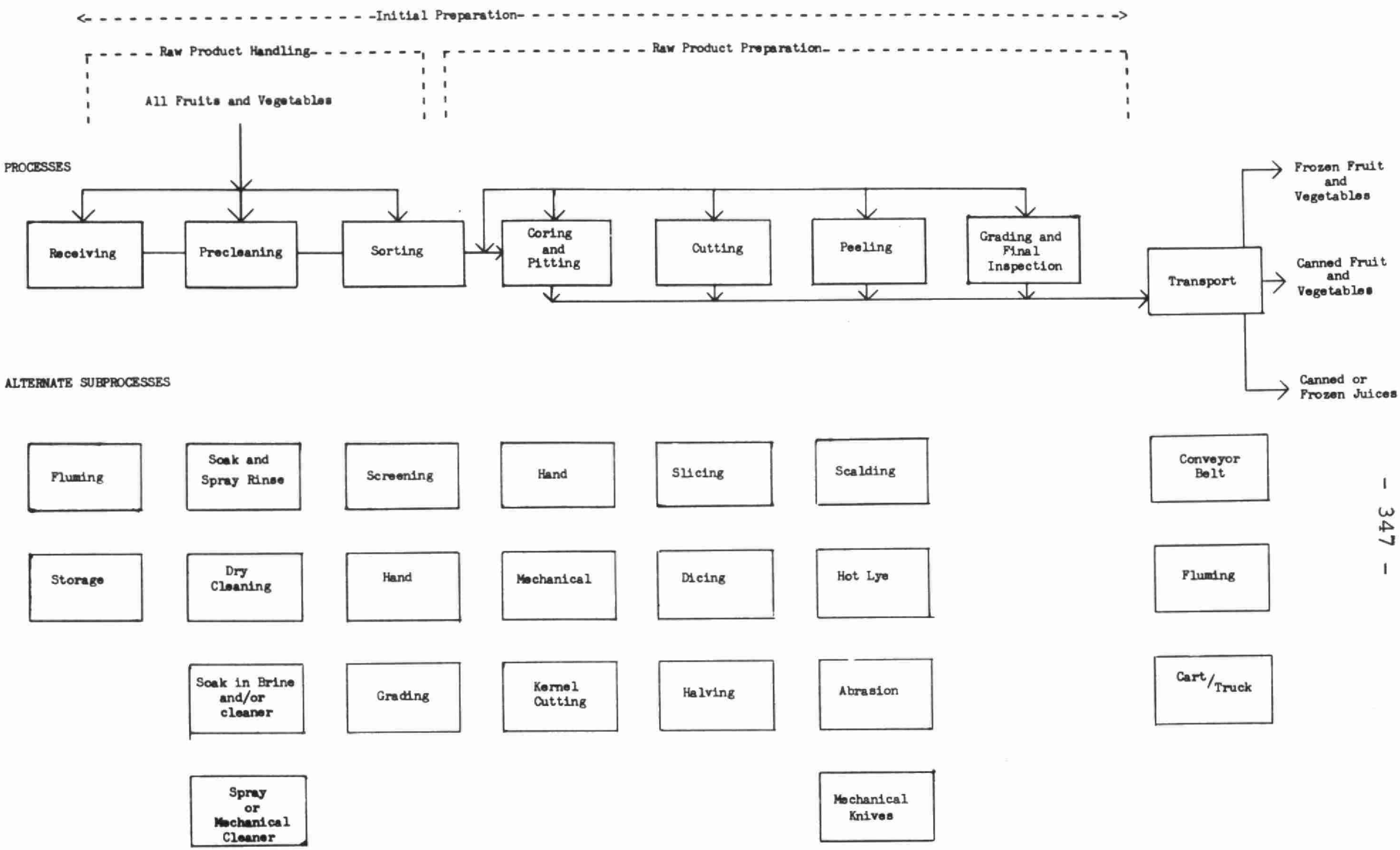

FIGURE II

SUMMARY FLOWSHEET FOR FRUIT AND VEGETABLE PROCESSING

FROZEN FRUITS AND VEGETABLES

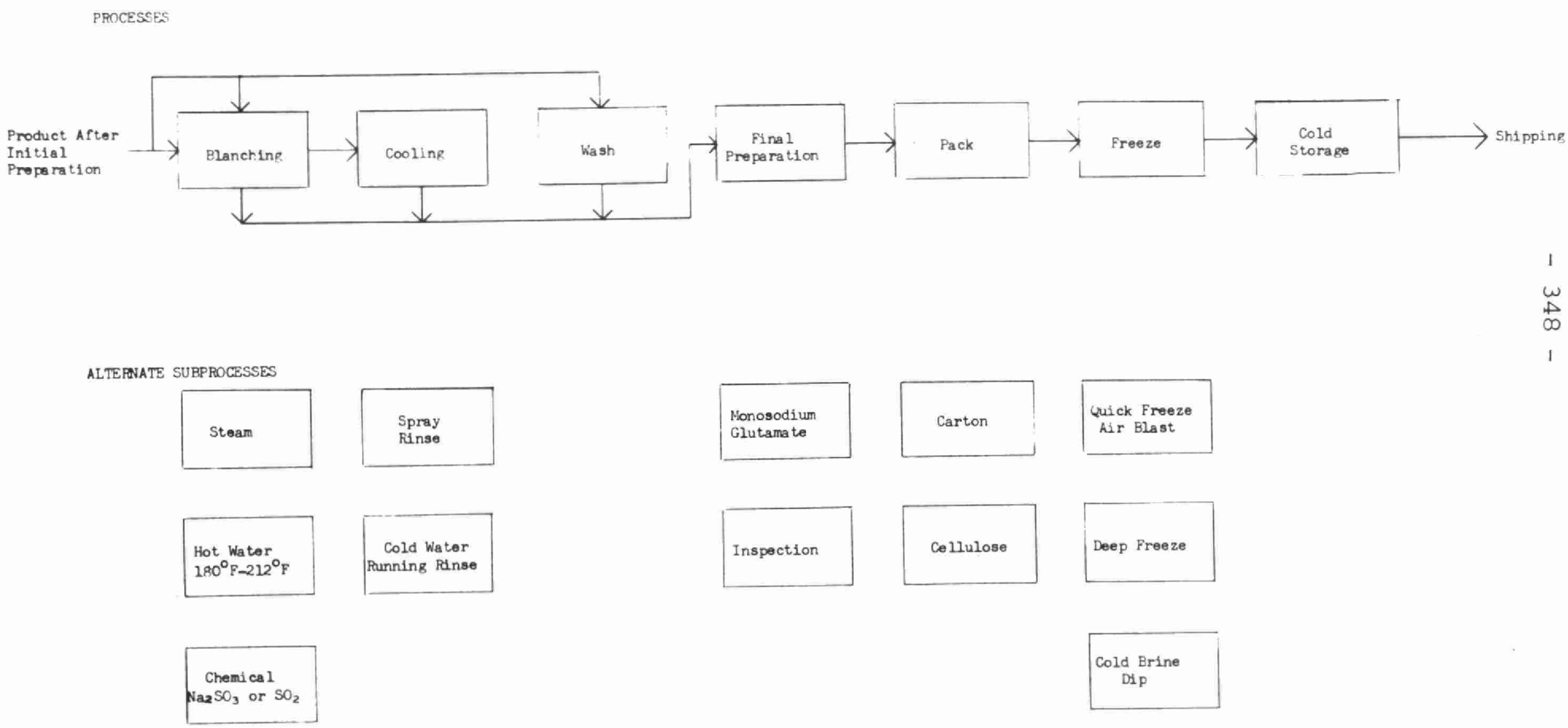

FIGURE III

SUMMARY FLOWSHEET FOR FRUIT AND VEGETABLE PROCESSING

CANNED FRUITS AND VEGETABLES

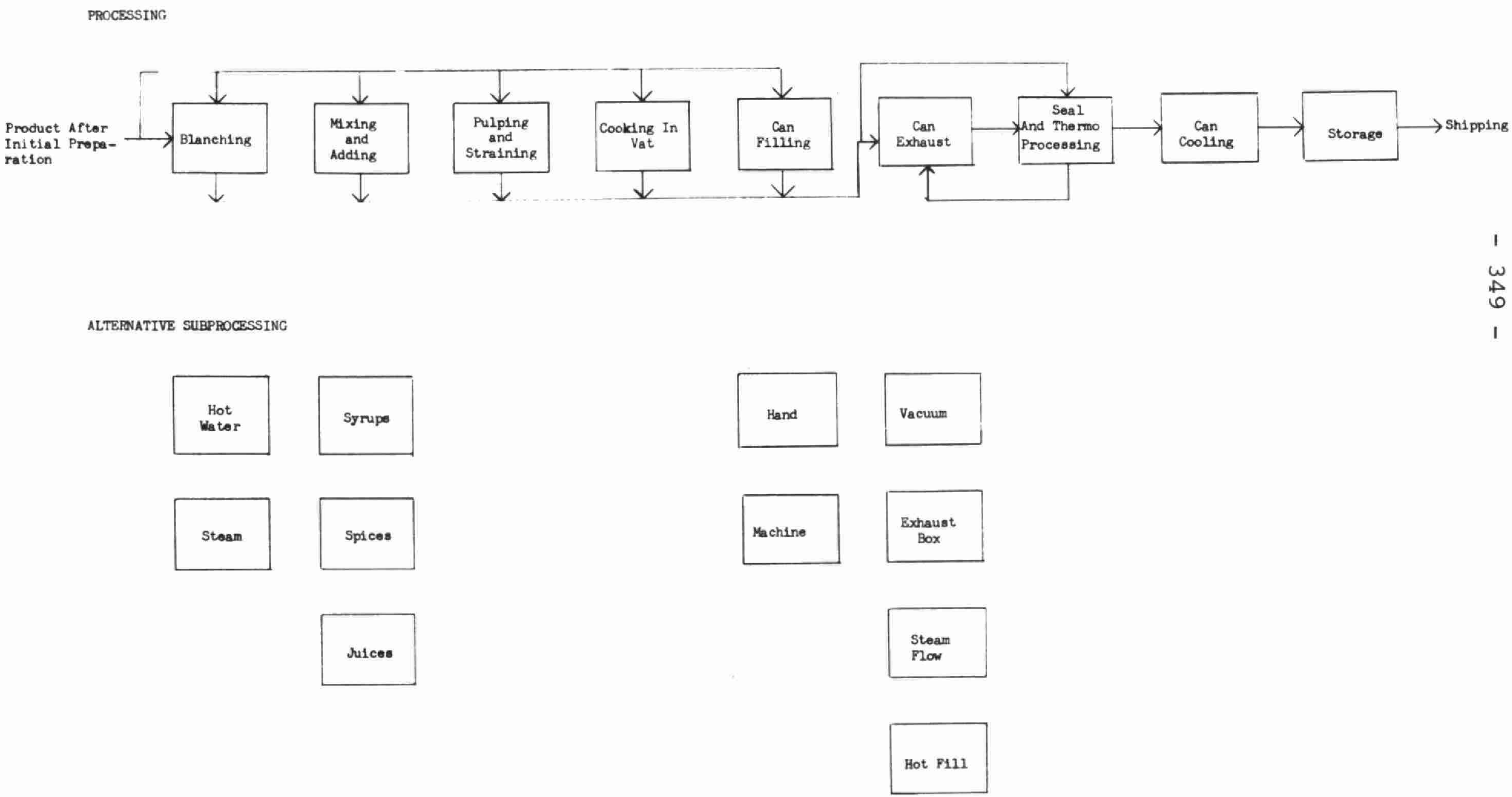

FIGURE IV

SUMMARY FLOWSHEET FOR FRUIT AND VEGETABLE PROCESSING

CANNED AND FROZEN FRUIT JUICES

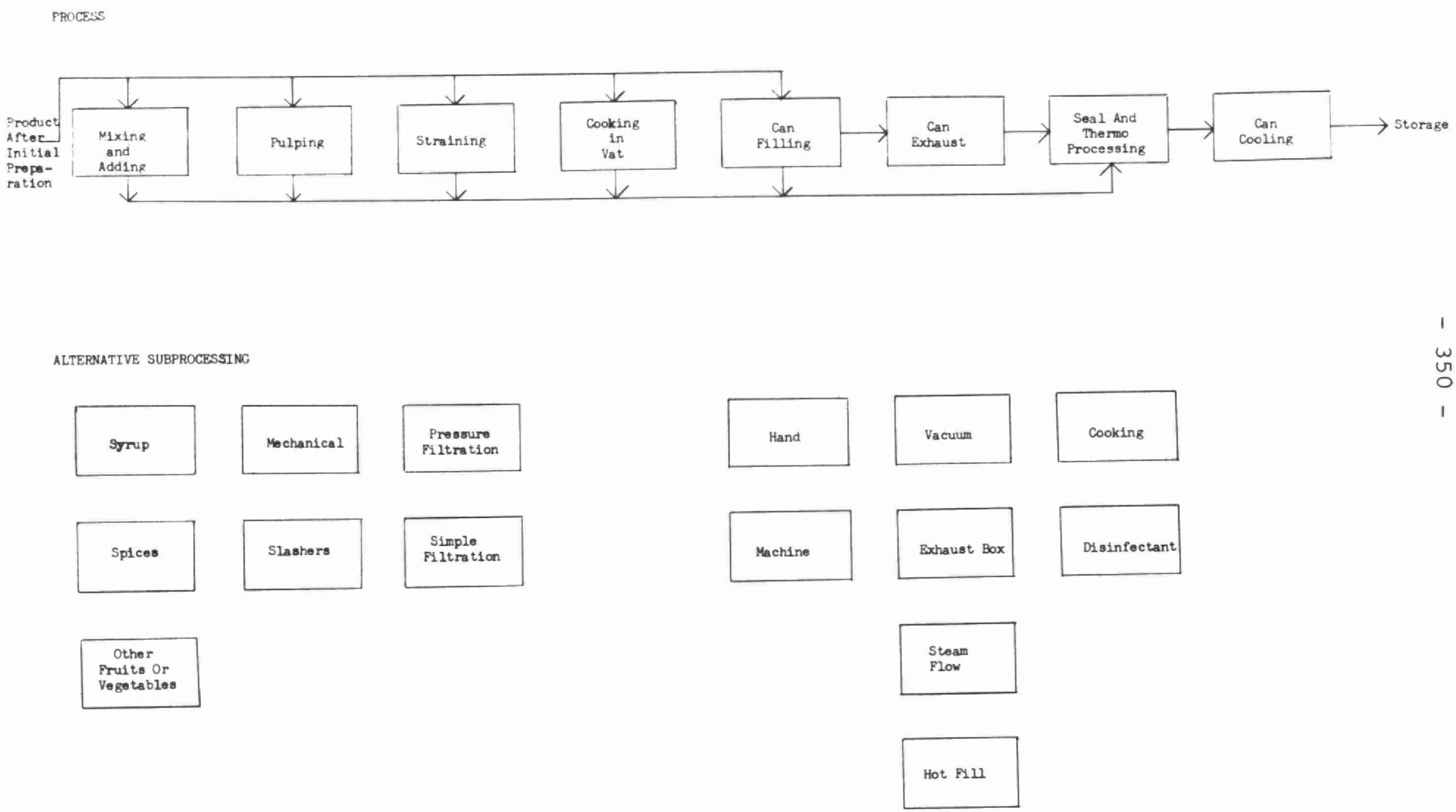

FIGURE V

TYPICAL PEACH CANNERY PROCESSING

WATER USES AND SOURCES OF WASTES

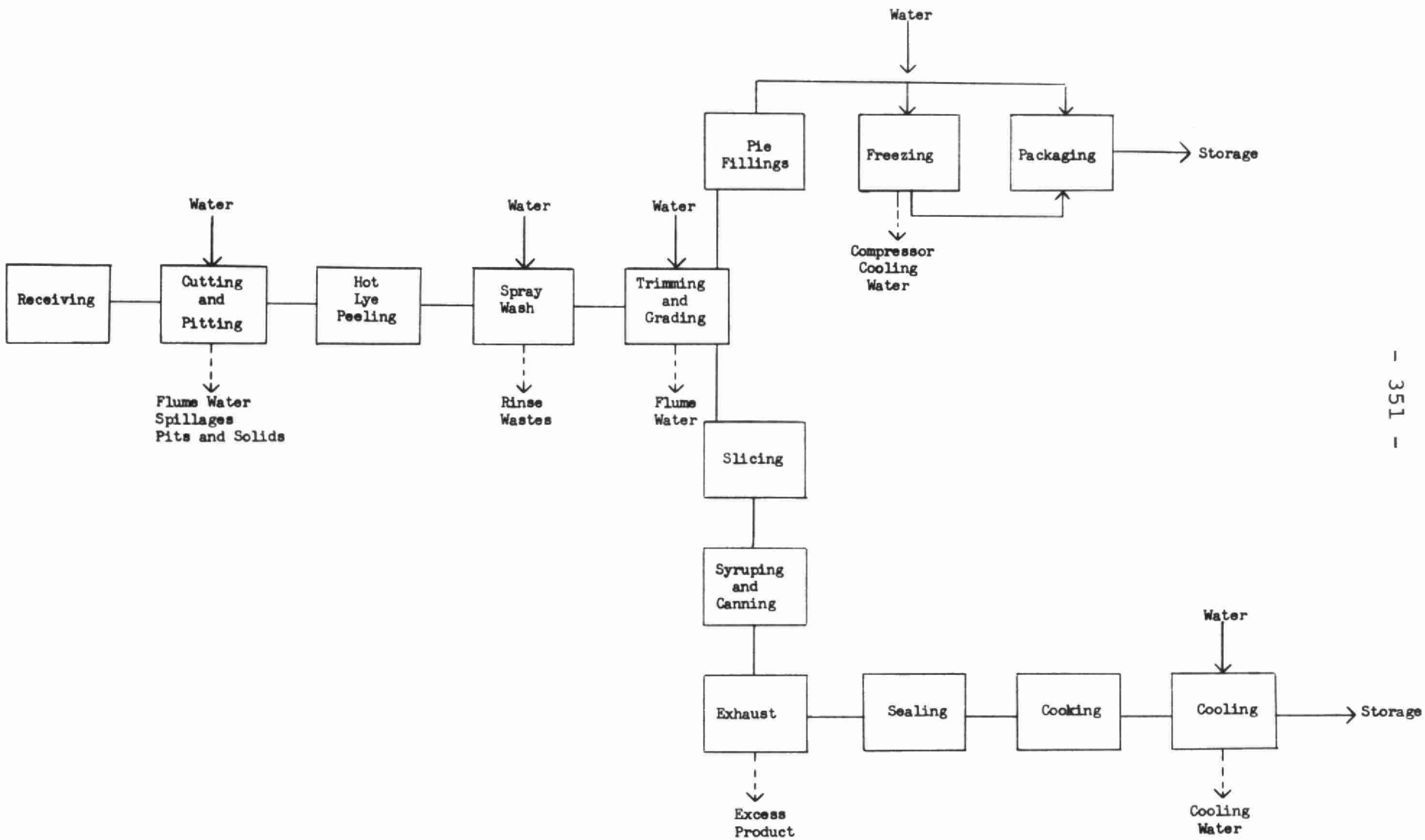

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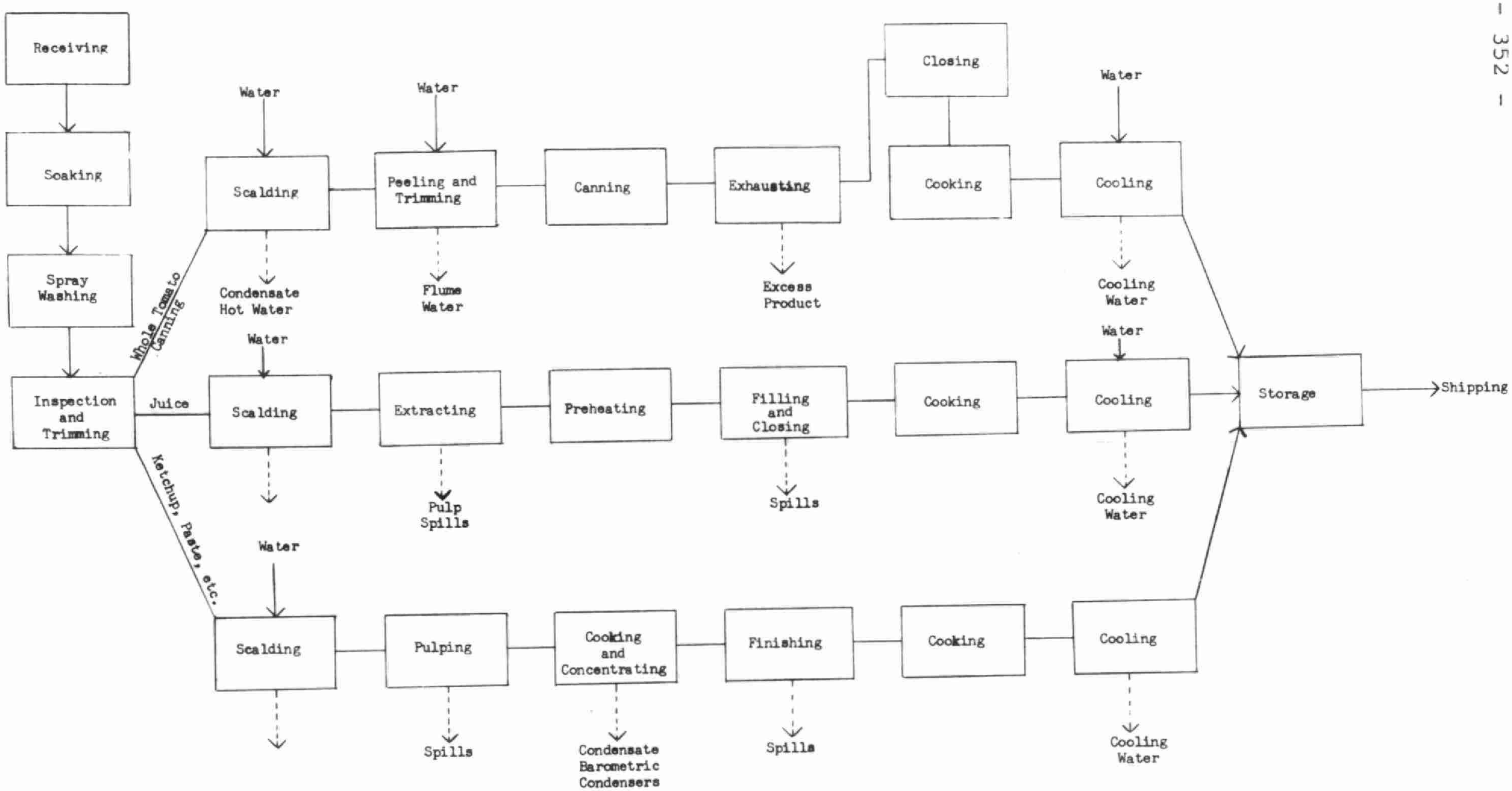
FIGURE VI

TYPICAL TOMATO CANNERY PROCESSING

WATER USES AND SOURCES OF WASTES



considered as being amenable to treatment and for this reason this practice has been considered as an excellent means of disposal. This practice, however, does have serious drawbacks as indiscriminate seasonal discharges of cannery wastes to a sanitary sewer may cause serious operational problems at the sewage treatment plant.

In general municipal waste treatment systems fall into the three main categories of primary treatment, activated sludge and lagoons. Each of these systems reacts differently to cannery wastes and consequently each system will be discussed separately.

(1) Primary Treatment Plants

Primary treatment plants work on a very simple principle where part of the BOD and suspended solids is removed from the wastes by simple sedimentation. The wastes remain in a retention tank (clarifier) under more or less quiescent conditions during which time the entrained solid material that is allowed to settle out is removed from the bottom as a sludge. The relatively solid-free supernatant is discharged as the treated effluent.

In general cannery wastes receive minimum

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treatment at a primary sewage treatment plant. Most of the entrained solids are of a fibrous nature and consequently do not settle out very readily. A major portion of the BOD is in a soluble form and certainly very little of this is removed by simple sedimentation. If unscreened cannery wastes are discharged to a primary sewage treatment plant, only 50% of the suspended material is removed during treatment. If proper screening is carried out at the cannery the above figure may drop to about 30%.

Unless the cannery is located within a municipality or rather in a built up residential area, it may be more practical to provide primary treatment at the industry. This would remove a significant hydraulic loading from the municipal plant resulting in better treatment of the sanitary wastes. As primary treatment facilities are neither complicated nor difficult to operate, they should be easily afforded by most canneries. If the municipal primary plant is later to be expanded to include secondary treatment, the treatment facilities at the industry could provide excellent pre-treatment and good equalization of wastes to permit the discharge of the process wastes to the sanitary sewer.

(2) Secondary Treatment Plant

An extension of the primary treatment plant is the activated sludge plant which uses a bacteria to treat for BOD removal. Cannery wastes can exert extreme shock loads on municipal plants employing an activated sludge process, enough to upset the operations entirely. Until proper operations are restored at the plant, treatment efficiencies may drop say 25% resulting in an effluent of extremely poor quality being discharged to a natural watercourse.

It is extremely difficult to acclimatize an activated sludge plant to cannery wastes because the waste volume and quality varies considerably from day to day as well as from pack to pack. In some cases, because of the strength of the process effluents, the waste loading from the cannery may equal or exceed the municipal contribution. If the municipal facilities do not have any reserve capacity, the treatment plant can become severely overloaded and produce a poor quality effluent. The cannery wastes may also be nutrient deficient and may retard the growth or build up of sludge at the municipal plant. In these cases nutrients would have to be added in the form of nitrogen and/or phosphorus at the industry or at the treatment plant when the canneries

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are in operation and cannery wastes are being treated depending upon the agreement arrived at between industry and municipality.

Before cannery wastes can be accepted at an activated sludge plant, some form of pre-treatment at the industry is required. Pre-treatment normally consists of wastewater segregation, screening, equalization, and in some cases aeration. It is first essential to separate the clean wastes (cooling waters) from the process wastes normally for direct discharge to a watercourse or storm sewer to reduce the hydraulic loading on the sewage treatment plant. Screens are used to remove the coarse solids from the effluent to decrease BOD and suspended solids loadings. Screening is not a simple process because in some cases when vibrating screens are used the BOD concentrations in the waste may increase after the wastes pass through the screen since the shaking action has the tendency to transfer material from the solid to the liquid. The screening facilities should therefore be designed to suit the wastes.

Equalization of wastes is necessary to eliminate shock load effects on the activated sludge system. In these cases retention facilities are provided at

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the industry to hold the wastes for about 4-8 hours. The wastes are bled into the sewer at a controlled rate over a more prolonged period of time. The retention basin lets wastes of various strengths become mixed (e.g. washdown wastes and process wastes) and hence a more consistent effluent is discharged to the sewer. As the cannery wastes are even further diluted by the sanitary waste, in the sewer, the effects of the industrial discharge on the sewage plant operations become less noticeable.

In cases where the municipal facilities are definitely too small to handle the cannery wastes, the industry may be required to construct more complex pre-treatment facilities such as an aerated lagoon or even an activated sludge plant to reduce the bulk of the BOD loading. If the cannery produces strong wastes having BOD concentrations in the order of 2000 ppm to 4000 ppm, a treatment plant operating at 90% efficiency can only produce an effluent having BOD concentrations anywhere from 200 ppm to 400 ppm which is the conventional strength of normal sanitary wastes. The pre-treated effluent can therefore be discharged to the municipal facilities for final polishing.

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(3) Municipal Lagoons

In the smaller outlying areas of Ontario, lagoons are used to treat sanitary wastes. Although lagoons tend to absorb shock loads better than activated sludge plants they are still susceptible to high waste loading from canneries. The treatment efficiencies may drop considerably during the canning season if the waste loadings discharged to the lagoon exceed the design criteria. If insufficient oxygen is available the heavily overloaded portions of the lagoon may turn septic. This could easily result in the emission of obnoxious odours, especially during the spring during ice break-up.

To overcome the septic conditions, additional oxygen may be provided artificially through the addition of a nitrate. This should only be considered as a temporary solution. Aeration facilities could be installed and operated only during the canning season to handle the surplus waste load. During the remainder of the year the lagoon may have sufficient capacity to treat the sanitary wastes without aeration. Any expansion or modification to a municipal system to accommodate industrial waste should be paid for by the industry by setting up suitable cost sharing agreements.

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The capacity of the lagoon may be increased by constructing additional cells to handle the waste loading from the cannery. In the case where the waste loading from the cannery greatly exceeds the waste loading from the municipality, then this type of expansion may be impractical. Unless there is a suitable cost sharing agreement between the industry and municipality, the cannery should consider private forms of treatment.

PRIVATE TREATMENT

(1) Land Disposal

Canneries which operate their own wastewater treatment facilities normally dispose the wastes on land.

(a) Spray Irrigation

Spray irrigation, the more common means of land disposal, is an adaptation from the artificial watering of crops by a portable sprinkler system. The reasons why this system is attractive include low cost of operation, elimination of odour problems, and possible irrigation of edible crops. There are however a number of important design criteria that have to be met to make the system completely effective.

The wastes require proper screening prior to spray irrigation to prevent the blockage of the

spray nozzles. Fine screening is usually sufficient to have a trouble-free operation. A reservoir must be large enough to maintain continuous pumping and yet small enough to prevent the wastes from becoming septic.

The land of course is the single most important criteria. The soil characteristics and cover crop dictate the rate of applications and the number of acres required to handle the wastes from a particular cannery. The soil characteristics vary from excellent, a soil that is sandy loam, to poor, where the soil is predominantly clay. A good cover crop is essential to increase the rate of absorption, evaporation and transpiration, and to prevent the erosion and clarification of soil. With a good system it may be possible to spray three to four inches of wastes per acre per day with application rates not to exceed 0.4 to 0.6 inches per acre per hour. An area sprayed at this rate may be resprayed after about 4 to 6 days.

The system may be very easily upset if the optimum rate of application is exceeded. If the nozzles are not relocated and land is over-sprayed or saturated with rain, pools of wastes may start to build up. The obnoxious odours resulting from

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organic decomposition may become a public nuisance. If the land is sloped, over-application may result in heavy runoff with the drainage normally entering a watercourse. All of these problems may be overcome by the acquisition of more land to increase the spraying area and to reduce the volume of wastes applied per acre. It may be possible to collect the drainage or runoff for respraying under more amenable weather conditions or for discharge to a sanitary sewer for final polishing at a municipal sewage treatment plant.

Spray irrigation is most convenient to the smaller or medium sized canneries located in rural areas. Once the waste volume approaches 200,000 to 300,000 gallons per day, the cost of land becomes the critical and over-riding factor making other means of treatment far more economical.

(b) Haulage and Spreading on Land

The other means of land disposal is the simple hauling and spreading the wastes on land. Canneries using this means of disposal are normally very small, and because smaller plants have relatively short operating periods, few problems are encountered with this means of disposal.

Normally the process wastes are stored at the plant and then transported onto the fields by tank truck. Spreaders are used to apply the wastes on land uniformly to prevent the formation of pools. If sufficient land is available this is an excellent means of disposal as it provides for complete treatment without any discharge to a watercourse.

The only danger in this method of disposal is over application. Long standing pools may turn septic from organic decomposition and emit obnoxious odours. Also the fields may turn muddy in spots and become impassible to vehicles preventing further application. For a more efficient use of land the area can be ploughed after the wastes have been applied. If this is not an immediate solution to the problem, additional land would have to be acquired.

(c) <u>Ridge and Furrow</u>

The last means of land disposal is ridge and furrow. A plough is used to run furrows approximately 3 ft. deep and 3 ft. wide on the land making us of the area topography such that wastes introduced at one end of the furrow can flow by gravity to the other end. Wastes are simply discharged into a series of such furrows to seep into the ground. This is a good means of disposal only if smaller volumes of wastes are

to be gotten rid of and the ground is sandy and porous to permit good percolation into the soil. Again these systems suffer openly from hydraulic overloading or soil classification which reduces infiltration rates.

(2) Lagoons

There are quite a number of smaller canneries in the Province that use lagoons as total retention basins storing all wastes produced throughout the operating season during the winter months. In spring the contents of the lagoon are emptied to a watercourse at a controlled rate to take into account the dilution provided by the spring runoff. On occasions the wastes are spray irrigated in early spring or summer to empty the lagoon and prepare it for the next operating season.

In winter when there is an ice cover, the wastes are subjected to anaerobic decomposition, while in spring, summer, and fall, treatment takes place by aerobic decomposition. In both cases solids are removed from the effluent by simple sedimentation. From samples collected by Field Staff, primary indications are that the wastes meet the criteria for discharge to a natural watercourse in spring having BOD and suspended solids concentrations below 15 ppm.

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This fill and draw type of system works well providing the cannery is not located in a highly populated area. Because of the anaerobic decomposition that occurs in the water, these lagoons are usually sources of odours during the spring break-up. Even though this condition normally lasts for a few days, it may become a serious public nuisance.

To overcome odour problems masking agents may be used during the ice break-up or the lagoon may be aerated throughout the winter to keep the septic conditions down to a minimum. One dairy in the Province using such a system employed a small 5 HP aerator to provide sufficient oxygen to maintain the pond in an aerobic state all winter. Initial findings are encouraging and it is likely that similar systems could be used with holding ponds storing cannery wastes.

(3) Biological Treatment

The last type of treatment that the industry can install is some form of biological treatment. These systems include activated sludge plants, oxidation ditches and aerated lagoons. It is possible to have BOD removal efficiencies in the order of 90% producing and effluent that can be disposed of directly to a watercourse. These systems are complex

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and to describe them in detail would require the writing of separate papers. It is enough to say that these systems require the expenditure of considerable sums of money to cover installation and operating costs, and hence these facilities are constructed at the larger canning establishments.

DRUM RECONDITIONING

INTRODUCTION

Although drum reconditioning plants do not constitute a major industry in Ontario, they are worth mentioning in the context of this course since they produce a strong waste that requires treatment prior to disposal. Since this industry accepts drums that were previously used for many purposes, for example to contain varsol, pesticides, paints, varnishes, etc., the resultant wastes contain traces of these products and hence can cause serious pollution problems if discharged indiscriminately.

PROCESS OPERATION

The drums are received by truck or rail and are stored outside prior to processing. The contents of the drum are emptied, normally by hand, into a sump and are passed on for cleaning at the plant. The cleaning operation consists of subjecting the drums to various washes such as a primary wash, caustic wash, and water rinse. After drying, minor mechanical repairs are made and the drums are painted. The lids are also passed through a similar operation and are also painted prior to shipment. A general process flow sheet of the operation is shown on Figure I.

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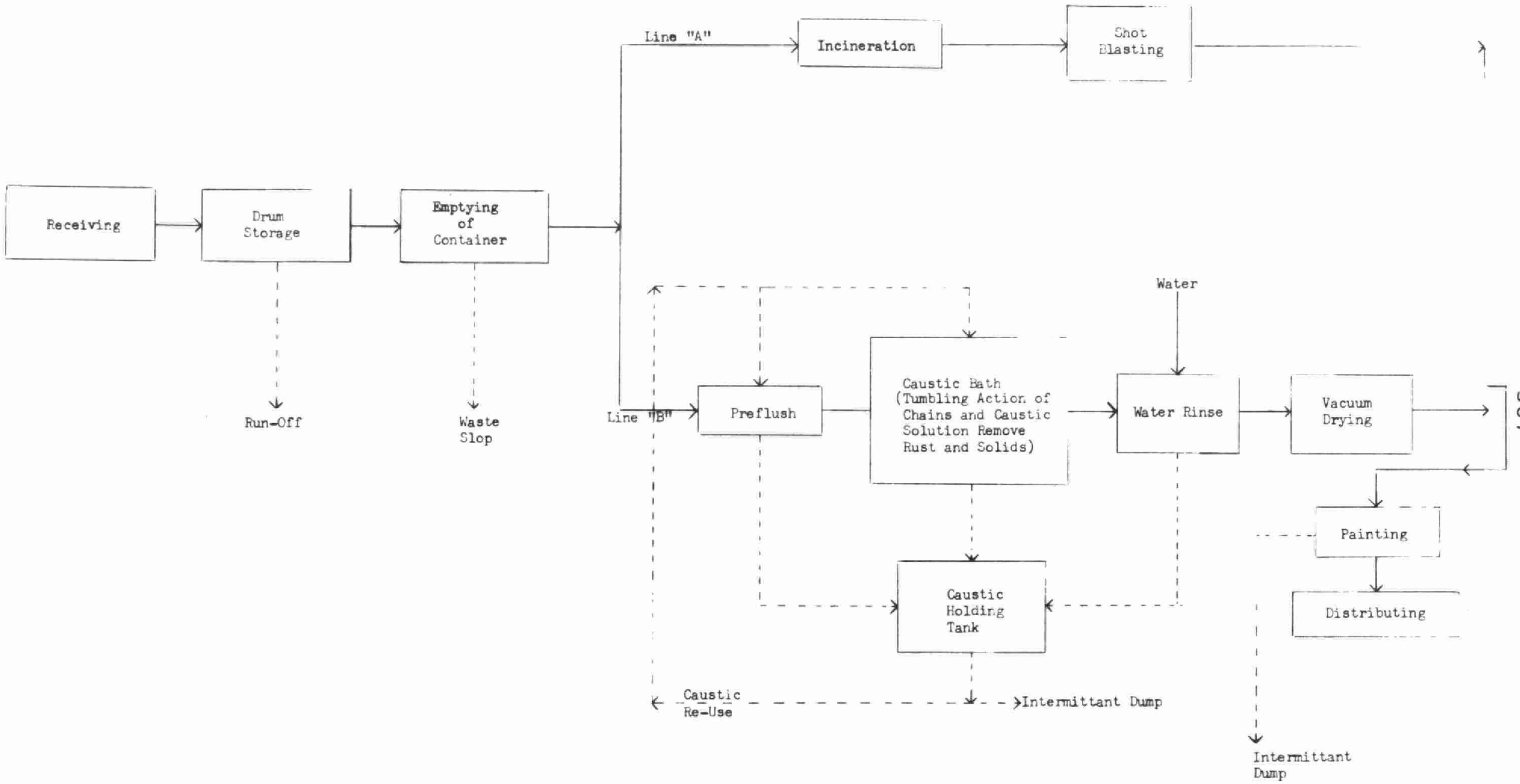
FIGURE I

GENERAL PROCESS FLOWSHEET



Line "A" - Open Head Drums (One End Open) for such products as paint, grease, adhesives.

Line "B" - Closed Head Drums (Closed Except for Outlet Ports) for such products as oil, solvents, liquid detergents.

COMMENT - Sulphuric Acid sometimes used instead of Caustic Soda in cleaning operations.

SOURCES OF WASTES AND DISPOSAL

When the drums arrive at the plant, they are removed from the transport vehicle and stored outside. Runoff from the storage pile would of course pick up residual materials spilled from the drums and hence this waste stream is a potential source of pollution. Drum storage areas therefore require the construction of concrete pads to prevent materials from seeping into the ground and gaining access to ground water. The area should also be dyked to collect runoff and convey it to a suitable treatment system.

Before the drums are passed into the plant for cleaning, it is necessary to empty them and remove the residual materials. These slops are normally collected in a sump to be hauled away to a suitable land disposal site. The contents of these drums may vary considerably and hence the slops may contain oils, varnishes, pesticides, paints, etc. Because of this, deep well injection is probably the best method of disposal.

The caustic preflush and caustic wash water would also pick up residual materials left in the drum. This waste water requires treatment since it may contain toxic materials lethal to aquatic life. Pre-treatment is also necessary since the waste may

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shock-load a sewage treatment plant and create operational problems.

The caustic wastes are disposed of periodically when spent, the volume varying with the size of the operation. This liquid effluent would require neutralization and clarification prior to discharge. It may also be necessary to pass this material through a separator to remove oils and greases.

The final water rinse would contain some caustic and hence would exhibit a high pH. Again, neutralization would be necessary before the waste can be disposed of. However, the final rinse water can be used for make-up in the cleaning operations

Painting of the drums and lids is normally done in a paint spray booth which has a water curtain to catch the paint droplets and prevent an excessive build up of paint on the booth walls. This water is normally recycled and paint solids are coagulated and skimmed off at intervals. The water itself will be dumped occasionally and will require treatment.

WASTE CONTROL

Before any treatment is attempted, every effort should be made at the plant to reduce the volume of

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waste produced through in plant control. If drums are wllowed to drain longer, less residual material would be transferred to the wash water, thereby reducing waste strength. High pressure sprays rather than running rinses could reduce the volume of wash water produced. As far as possible, wash water should be recycled.

Once in-lant control measures have been implemented, treatment of wastes would be required to render the effluent acceptable for disposal. Such treatment might include one or more of the following:

- pH adjustment
- oil separation to remove oil, grease, and surface scums,
- clarification to remove solids and metals precipitated during pH adjustment
- deep well disposal
- land disposal of solids
- haulage of strong liquid wastes for commercial treatment or disposal to a deep well
- incineration.

RAILWAY YARDS

INTRODUCTION

In the early days of railways there were numerous yards scattered throughout the province acting as intermediate fuelling depots, water reservoirs, maintenance shops, etc. The industry began to modernize and mechanize its operations and with more efficient engines running more miles on less fuel, the number of depots on the long runs was reduced. The depots along with small railway towns began to be phased out of operation and were replaced by more modern larger and centralized depots.

OPERATIONS

(1) Fuelling Depots

On extremely long runs, e.g., the trans-Canada route of the CNR or CPR, there are a number of fuelling depots located at strategic points where diesels are refuelled and water and ice for cooling purposes are taken on board. Considering the amount of time permitted to fill a diesel, and the volume of fuel required, there is invariably some oil spilled during the operation. In the past, this oil saturated the ground adjacent to the fuelling platform and in some cases even polluted the ground-water table. Surface runoff became contaminated with oil and was the source of pollution of neighbouring watercourses. In the more northern areas oil became trapped by winter

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ice and snow to be released en masse during the spring thaw. The fuelling depots were therefore required to implement control measures to contain the oil and prevent its access to a watercourse.

(2) Roundhouses and Car Shops

Heavier maintenance on the engines and cars is carried out at the roundhouse and car shops. Here motors, brakes, wheels, etc., are inspected and repaired either as part of a routine maintenance program or as required. The cars are washed and cleaned internally and both cars and engines are washed externally.

Roundhouse operations use relatively small amounts of water during washdown operations. Heavy machinery uses oils as a lubricant or for cutting purposes and some invariably is lost to sewer. Spent oils are normally collected and shipped in bulk, but it is impossible to contain all oil spills and hence any floor washdown operation would result in oil discharged to sewer. When the engines and cars are washed, soap and detergent cleaners are used and hence the liquid effluents contain oils in emulsion along with dirt and grit. In some cases steam generators are used which results in oily steam condensates being discharged to sewer.

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WASTE CONTROL & TREATMENT

(1) Fuelling Depots

The main source of oil pollution at the depot results from spills occurring during fuelling operations. Drip collection pads have been constructed on the tracks under the diesel engines to catch and contain spills resulting from poor hose connections. The oil is conveyed to a trap or separator and is recovered. Containing spills in this manner prevents oils from saturating the ground and eliminates runoff problems.

(2) Roundhouse & Car Shops

Roundhouse wastes contain oil and suspended solids. It is normally sufficient to pass the wastes through a large separator to settle out the solids and trap the oil. When detergents are used the oils become emulsified and cannot be readily removed by simple gravity separation and hence chemical treatment may be necessary to break these emulsions. To eliminate emulsions some yards use steam generators to clean diesels which also reduces the volume of wash water used. The steam condensate from this operation can very readily be handled in an oil separator. Good housekeeping practices have also reduced the frequency of oil spills and the amount of oil to to the sewer.

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From the car washing rack, there may be a waste which contains high concentrations of suspended and dissolved material. In the waste will be found traces of materials which were in the cars being cleaned. Since the range of materials carried is very wide, the quality of the waste will be quite variable and the treatment required to produce an acceptable effluent may be quite sophisticated.

Apart from the car and engine washing wastes, the problem to be resolved at railway yards is one of spilled oil. Therefore, oil containment and separation facilities are most important and must be installed whenever necessary.

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BULK LIQUID STORAGE

Bulk liquid storage may appear at first sight to be a topic somewhat out of place in a course on control of industrial wastes in municipalities, but on further reflection the pollution potential of these installations may become apparent.

The pertinence of this topic for inclusion in this course is based on two factors:

(1) Many large storage installations are located within urban municipalities, and

(2) Leakage of the stored material may, if of sufficient volume, flow into storm sewers or even into sanitary sewers.

Since most stored materials are environmentally hazardous if released in quantity, it is obvious that bulk storage of liquids should be included in a programme for municipal control of industrial wastes. The fact that no waste is produced on a day-to-day basis is irrelevant - it is the enormous potential for pollution which is of concern.

Before proceeding, consider a short list of some of the liquids commonly stored in bulk; gasoline, nitric acid, ammonia, bunker fuel oil, trichloroethylene, ammonium hydroxide, sulphuric acid, alcohol, benzene,

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glycerine, asphalt, hydrochloric acid, caustic soda and others too numerous to mention. You will see, even from these few examples, that the variety of materials is so great that losses involve a large number of clean-up techniques, often difficult and costly techniques.

A liquid stored in bulk can cause no pollution problems as long as it remains properly contained. Containment, therefore, is the vital key to control of pollution by liquids stored in bulk. Here, it must be stressed that retention of a spilled liquid as close as possible to the point of spillage is mandatory. This is stated in full knowledge that vigorous opposition will be encountered from those persons who, ignorant of the basic principles of pollution control, advocate immediate and widespread dispersal of any accumulation of spilled liquid. Consider the following example. A tanker vehicle carrying gasoline is involved in a traffic mishap and gasoline leaks from the tank. Invariably the first action of those responsible is to flush away with water the spilled material, thereby "eliminating" a severe fire hazard. However, as you are aware, water and gasoline do not mix and by flushing, the fire hazard has merely been removed from a purely local area and has been spread through perhaps many miles of sewers. Not only has the hazard been spread, it has actually been

increased since persons remote from the site of the spill are exposed to the gasoline - but are unaware of its presence. In addition to the hazard to persons, there is of course the damage to the environment which must be considered. Therefore, it is stated again that no matter the nature of a spilled liquid, it must be retained as close as possible to the site of the spill.

It is, of course, very easy to contain spills from a static installation, but it is much more difficult to provide the same protection in the case of mobile tanks. The methods used in containing spills from tanker vehicles depend so much upon the circumstances of the spill that they will not be discussed here.

The following applies to stationary tanks.

When a material is spilled, there are two ways by which it may tend to move away from the spill site, either on the surface of the ground or below the surface, and in many cases both will be of concern. Obviously it is desirable to eliminate the possibility of spilled material soaking into the ground and the first step towards containment therefore is to ensure that the site is provided with an impervious surface. If this is done and a spill occurs, the liquid, being unable to soak into the ground, will tend to flow away towards the low point.

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The second step towards containment, therefore, is to ensure that there is an impervious dyke or wall around the perimeter of the site, of a height such that the volume enclosed is greater than the volume of the largest tank. When these two steps have been taken, any liquid falling within the impounded area will be trapped and may then be removed for proper disposal. Of course, rain falling within the area will be trapped, but can be removed by pumping to the outside of the dyke or wall where it may flow into the storm sewers. Obviously, if rain water becomes contaminated while within the impoundment, it must not be disposed of by pumping to the storm sewer system. It is apparent, therefore, that the drainage within the impoundment should be such that all liquid flows to a small sump from which it can be pumped out for treatment and/or disposal. A common method of allowing rain water to escape from an impoundment containing tanks in which petroleum products are stored is via an oil separator at the lowest point. However, this type of system has been shown to be less than satisfactory due to its inability to handle widely varying flow rates (for example during a heavy rain storm) with consequent flushing out of any contaminant previously trapped. For this reason, removal of liquid from within the impoundment should be by pumping only. In the case

a liquid which floats on water, the pump intake should be at the bottom of the sump and pumping should cease before the contaminant layer nears the intake. In the case of a liquid which mixes with water, pumping to the sewer is not permissable unless adequate treatment of the material has first been carried out. Pumping into tank vehicles for transportation to an ultimate disposal site is of course allowable.

From time to time, liquid will be added to and withdrawn from a tank and precautions must be taken to ensure that pollution does not result from leaks from pipes, pumps and other equipment. All equipment, therefore, where possible, should be within the containment area or should be drained into it. As an example, where liquid is being transferred between a road tank vehicle and a bulk installation, a specially constructed impervious pad should be constructed upon which the vehicle should stand while the transfer of liquid is being carried out. The pad should be graded and drained in such a manner that spilled liquid would be retained or would flow into the impoundment area.

The simple retention systems which have been described may be implemented where tanks are above ground and are not of very large volume. Very large tanks, for structural and economic reasons, must rest upon the ground and usually a sand base is prepared before the tank is placed. Leakage from the tank bottom, therefore, would not immediately be apparent as the liquid would soak into the ground. The best defence against such an occurrence is exhaustive testing of the tank before it is put into service, but even where this is done, leaks may occur. In such cases retention is almost impossible to achieve and early detection of a leak therefore is vital. Probably the most economical means of detecting a leak is to install at strategic points around the site test wells which would be inspected regularly for indications of the presence of the material stored in the tank.

Apart from the area immediately under the tank, an impervious surface may be laid over the remainder of the site and a dyke may be constructed to enclose a volume larger than that of the largest tank within the impoundment. As before, any liquid falling within the dyked area may be pumped out for proper disposal.

Where tanks are underground, a system of test wells should be installed as previously described. However, as an ideal, no tank should be buried. Rather, a pit should be prepared of concrete or other structural material, of sufficient size that there would be space around the tank to conduct inspections. No drainage should be allowed from the pit and any accumulation of liquid should be removed by pumping out. The pipes leading from such tanks should be above ground or if that is impossible, the pipes should be laid in a liquid-tight trough which should be drained to the tank pit. Precautions for transferring liquid between the tank and, for example, a road tank vehicle should be taken as already described.

Apart from the steps which should be taken to retain spilled liquids, there should be at each site a supply of material and equipment for use when a spill occurs. For example, if hydrochloric acid is spilled there must be immediately available a supply of water for dilution and a quantity of alkali for neutralization. In case of a spill of a highly flammable liquid, foam generators should be available. It should be stressed, however, that procedures and equipment for dealing with spilled liquids must be approved by a knowledgeable and competent person if serious accidents are to be avoided.

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While the measures described above would successfully prevent spilled liquid entering sewer systems, prevention of spills obviously is to be desired. Therefore, maintenance of all equipment and training of employees are extremely important. Conscientious and knowledgeable employees are the best insurance against pollution from bulk liquid storage installations. Where there are such employees, first class maintenance will be a matter of course and problems will be few. It is your responsibility to ensure that such a happy situation exists at all installations and you may have to undertake "education programmes" for the management and staff of those companies where conditions are less than satisfactory.

In summary, the following are a set of ideals which if implemented will result in many fewer cases of pollution from bulk liquid storage facilities;

(1) Buried storage tanks are undesirable.

(2) Underground pipes are undesirable.

(3) An impervious surface at the storage area is desirable.

(4) A dyke or wall around the storage area is desirable.

(5) Properly designed loading and unloading facilities are desirable.

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(6) Supplies and equipment for dealing with spills are desirable.

(7) First-class maintenance and employee training are desirable.

While it may not be possible to implement all of these at all sites due, for example, to safety considerations, they should be regarded as a code of desirable practice in the majority of cases. If you are able to convince the operators of bulk storage installations that these "rules" are desirable and necessary, it is certain that the incidence of pollution from these sources would be greatly diminished.

SERVICE STATIONS

AND

GARAGES

In Canada, there are in excess of 30,000 branded retail outlets which dispense gasoline and fuel oil. Of this figure, approximately one-third, or 10,000 outlets, are to be found in the Province of Ontario. In the year 1971, these 10,000 retail outlets dispensed more than two and one-quarter billion gallons of motor gasoline and over seventy-five million gallons of lube oils and heavy greases. Combined with these figures is the fact that in the Province there are in excess of two and one-half million passenger cars, 400,000 trucks and 13,000 buses. When one considers the number of vehicles in the Province and the resultant number of oil changes and lubrications required, it is not hard to realise that it is essential that the accidental spillage of petroleum products within the station be kept at a minimum.

Most, if not all, service stations located in municipalities are equipped with standard API interceptors with treated effluents directed to the sanitary sewer system. All floor drains within the confines of the station should be directed to the interceptor. If properly maintained, the interceptor has the ability to remove the petroleum product which contaminates the ordinary flows from the station. It is essential that routine maintenance of the interceptor

be performed by the individual lessee in order to ensure that the interceptor functions as designed. The oils and lubricants that are pumped from the interceptors at specific intervals must be retained in holding tanks. Until recently, the service station operator has had little trouble in having these tanks pumped periodically by companies that would take the spent oil to various locations where it would be re-refined or be utilized in some other manner. However, due to the tremendous increase in the quantities of used oil, the various liquid haulage companies are now charging the service station operator two to three cents per gallon to dispose of the oil. As this service is now charged to the lessee, the ultimate disposal of the oil is now up to the discretion of the station owner. For the most part, all stations continue to have oil removed by haulage companies. However, in certain instances, unaccountable and perhaps avoidable accidents resulting in the discharge of oil from a service station to a ditch or nearby watercourse have been reported. Increased surveillance of these stations, therefore, must be maintained by the municipality to ensure that the oil is disposed of in a totally satisfactory manner.

Another source of contamination from service

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stations is that of leaking underground gas tanks. Although all operators are required by law to maintain a record of daily dips of underground storage tanks, it is not uncommon that these tanks will spring leaks which can go undetected for a considerable length of time. This may result in some groundwater contamination and in certain cases notification has been received of gasoline seeping into basements of adjoining houses. Unfortunately, under present legislation there is little that a municipal official can do to ensure that underground storage tanks are continuously maintained to avoid leaks.

As shown in the appended drawing of the standard service station interceptor, each chamber has its own manhole and cover which is necessary to allow for proper cleanout of the unit at a specific time interval. The flow of petroleum contaminated waste enters the interceptor from the left. The siphons between the chamber, each of which is six inches from the bottom of the interceptor, allow the oily material to accumulate at the surface and only clear water to overflow to the adjacent compartment. The discharge from the interceptor should, therefore, be free of ether soluble material.

Occasionally, the periodic maintenance programme is neglected and a build up of solids occurs thereby reducing the separating capabilities of the unit.

A common occurrence is to have a correctly designed separator hooked up, unknowingly perhaps, to a storm sewer. This compounds the problems resulting from improper maintenance.

An accepted practice at many service stations is to use acid from trade-in batteries to clean the grease and oil covered floors. The solution is washed down the drainage system and depending on the volume of water mixed with the acid, could affect the operation of the separator or result in damage to the sewers. A special check should be kept on the larger stations and garages to ensure that this practice does not adversely affect the sewer system.

Occasionally, some stations will perform oil changes outside the buildings or stockpile empty oil tins or drums in a location where subsequent rainfall will result in an oily runoff. This runoff could be a serious problem if the station or garage is located on the bank of a watercourse or has storm sewers that drain to the creek.

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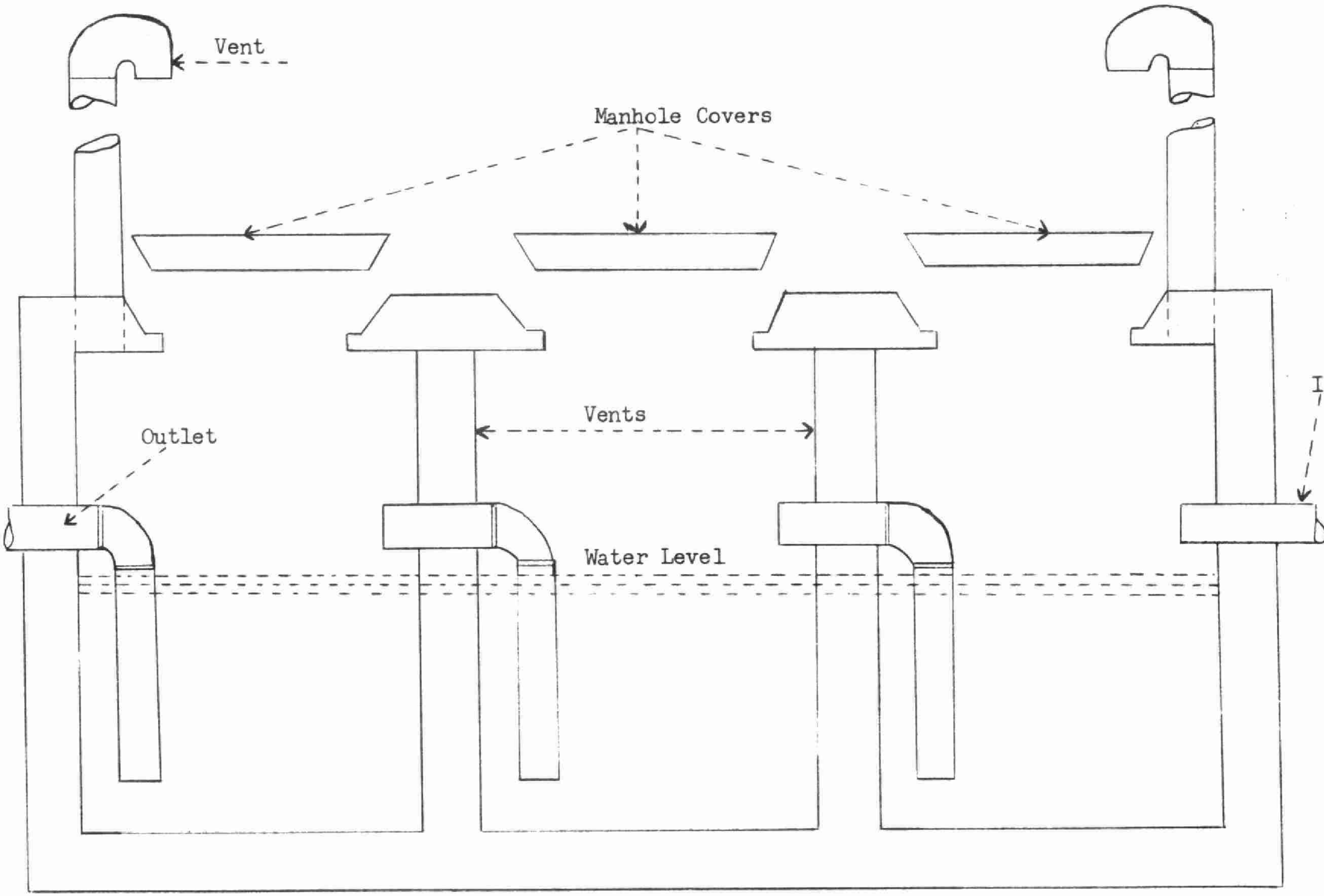
In conclusion, surveillance both inside the buildings and around the property of the station or garage is required to ensure that pollution problems resulting from operations at local service stations or garages are kept to a minimum.

SERVICE STATION

OIL INTERCEPTOR



CAR WASHES

Waste discharges from car washes are not generally problem discharges. The BOD's are usually under 100 parts per million, pH in the 6-8 range, grease 20-40 parts per million and suspended solids can vary from less than 100 to 600 parts per million. As one can see, this type of waste is innocuous to the modern sewage treatment plant. For the most part, all car washes have at least a three-stage interceptor to provide a partial treatment of the waste flow by removing some suspended material and grease.

There are three different types of car washes:

The first type which has sprung up recently, is the coin operated do-it-yourself unit, where the car is driven into a bay and the car is washed with a high pressure water and detergent solution and then rinsed with clear water. The effluent from the wash bay is discharged to the sanitary sewer either with or without benefit of an interceptor, depending on municipal by-laws. These units normally operate on a five minute cycle and a rough estimate of volume used per car would be in the range 75-100 gallons.

The second type is the "roll-over" unit. Here

the car is parked in the bay and the brushes and applicators move over and around the vehicle. In this facility, an interceptor may or may not be used, again depending on municipal by-laws, and the volume required to wash a car is approximately 150 gallons.

The third type is what is known in the trade as a "conveyor" car wash. In this unit, the car is driven onto a chain assembly and drawn through a tunnel. In this type of car wash the volume of water used per car varies considerably depending on the amount of time the car spends in the tunnel. On a slow day, the car moves through the tunnel more slowly thus receiving a better wash job and using more water. On busier days, the reverse is the case. The average water consumption in the conveyor system is 50 gallons per minute. In older installations of this type, all water is discharged to a sump and overflows continuously to the sanitary sewer. Some years ago, the economics of reclaiming some of the water became evident and the piping was changed to allow the first flood on the car to be made up of reclaim water, that is, the water that is reused in a closed loop system with the only treatment provided being solids removal. Incidentally, it was found that by using reclaim water, which was slightly

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abrasive and contained some detergent, the car was washed cleaner than when fresh water was used.

A more modern method presently being investigated by Imperial Oil Enterprises Limited and in use in Sarnia and Bridgeport, Ontario, is that of total reuse. In each portion of the car wash cycle, the first flood, the application and the final rinse, the water is recirculated within each stage. Each stage is equipped with a gravel filter and a carbon filter which serve to remove suspended solids, wax and some of the detergent. While this unit operates on a total recirculation basis, in order to keep the dissolved solids concentrations as low as possible, it is necessary to discharge 5-10 gallons of water at the end of the day's operation. In locations where there are no sanitary sewers this small flow is directed to a septic tank and field tile system.

One of the problems inherent in the total recirculation system occurs in the winter months when the build-up of chlorides that results from road salt applications contaminates the recirculated water to such an extent that intolerable spotting of the car occurs. Since no economical method has so far been devised to counteract this problem, it is necessary

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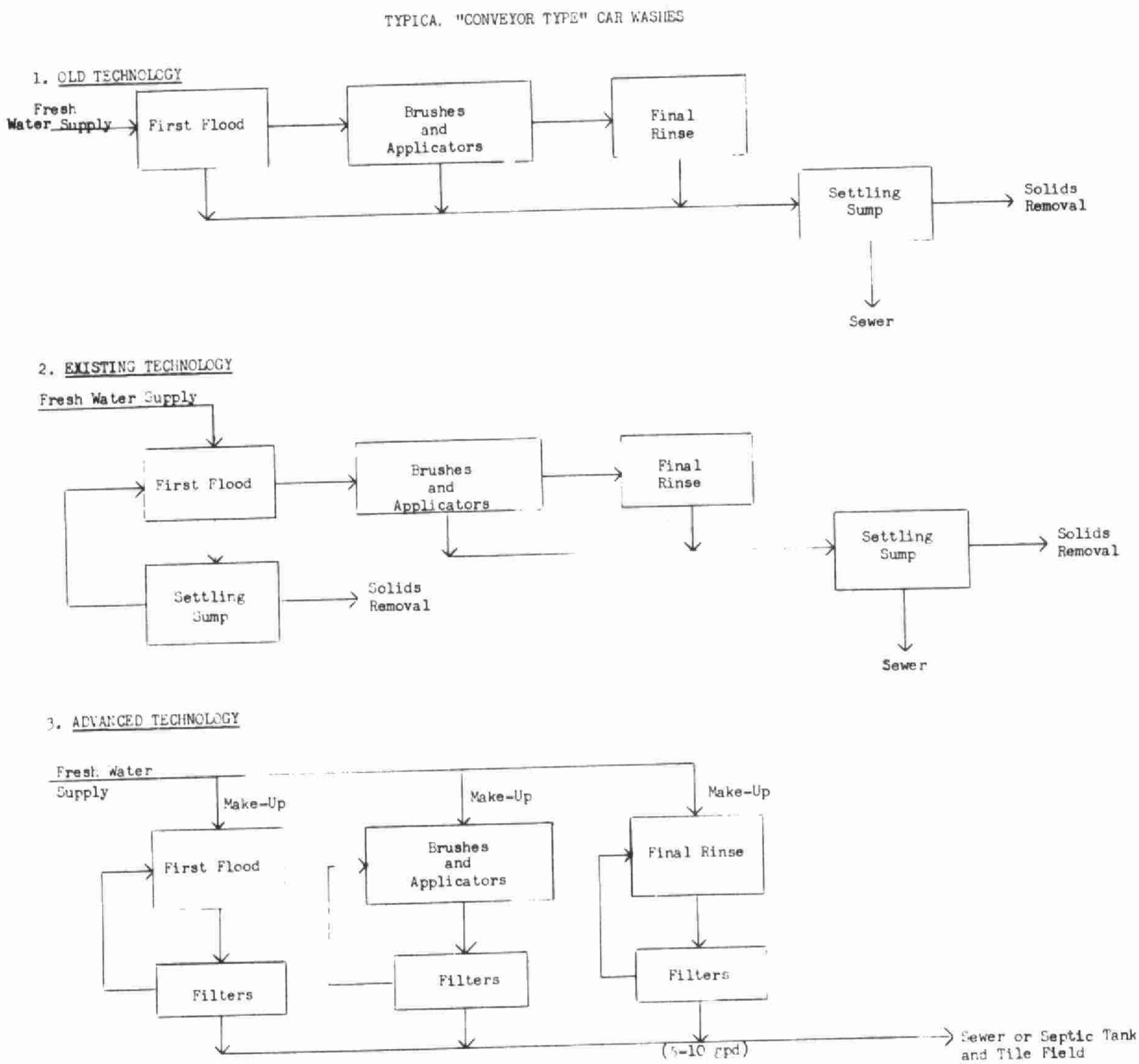
to have the chloride-saturated solution pumped out at certain intervals and disposed of in an acceptable manner. Imperial Oil utilises liquid haulage companies to perform this service. Another characteristic of the total recirculation system is that at periodic intervals the two filters must be backwashed. The backwash is also removed by a liquid haulage company for disposal. The principle advantage of the total recirculation system is that much less water is necessary to wash a car compared to the 100-200 gallon figure which is characteristic of the older type of car wash. One can easily see the economic as well as the decreased hydraulic flow benefits from the newer system. The attached drawing shows the three systems described.


TYPICA. "CONVEYOR TYPE" CAR WASHES
1. OLD TECHNOLOGY
Fresh Water Supply
First Flood
Brushes and Applicators
Final Rinse
Settling Sump
Solids Removal
Sewer
2. EXISTING TECHNOLOGY
Fresh Water Supply
First Flood
Brushes and Applicators
Final Rinse
Settling Sump
Solids Removal
Settling Sump
Solids Removal
Sewer
3. ADVANCED TECHNOLOGY
Fresh Water Supply
Make-Up
Make-Up
Make-Up
First Flood
Brushes and Applicators
Final Rinse
Filters
Filters
Filters
(5-10 gpd)
Sewer or Septic Tank and Tile Field

CHEMICAL MANUFACTURING

This broad classification of industry may be sub-divided into the following categories:

(1) ORGANIC CHEMICAL SYNTHESIS

(a) Aromatic Solvents

(b) Basic Raw Materials - Olefins, etc.

(2) ORGANIC CHEMICAL PROCESSING

(a) Polymers - Rubber, Plastics, PVC, Polyolefins

(b) Synthetic Textiles - Dacron
- Nylon
- Acrylics

(c) Detergents - Alkyl Benzene Sulphonates

(d) Agricultural Chemicals - Fungicides
- Herbicides
- Insecticides

(e) Rubber Chemicals - Stabilizers
- Accelerators
- Antioxidant

(f) Chemical Specialities - Corrosion Inhibitors
- Descalers
- Defoamers
- Cleaners
- Slimicides

(g) Pharmaceuticals

(3) INORGANIC CHEMICAL MANUFACTURING

(a) Sulphuric Acid

(b) Caustic Soda and Chlorine

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(c) Soda Ash

(d) Fertilizers

(4) PACKAGERS AND FORMULATORS

Many of these categoreis are unlikely to discharge process wastes to municipal sewers and they have not been dealt with in any detail in the discussion which follows. However, with proper segregation of process wastes from high volume cooling water discharges the potential does exist for some of these categories to discharge to municipal sewers. For the purposes of this discussion, it can be generally assumed that the large chemical plants manufacturing basic chemical raw materials and the large capacity secondary manufacturers do not discharge process wastes to municipal sewers. The small secondary manufacturing plants processing the basic raw materials usually discharge to municipal sewers and are of prime importance in the context of this course.

It is with these considerations in mind that the following brief summary of the nature of the waste discharges from the major industrial categories listed previously is presented. Greater emphasis will be placed on the secondary manufacturing plants which will

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be more pertinent to municipal situations:

CHARACTERISTICS OF CHEMICAL PLANT WASTES DISCHARGED TO NATURAL WATERCOURSES

(1) ORGANIC CHEMICALS SYNTHESIS

This category encompasses the broad class of petroleum and petrochemical processors manufacturing and/or extracting the basic organic raw materials for the plastics, polymers, rubber, agricultural chemicals and pharmaceuticals industries; usually from petroleum-based feedstocks. Also included in this category are chemical plants associated with the major steel mills processing coke oven liquors and coal tars.

The wastes from this broad industry group may be generally classified as having a high organic content, including dissolved hydrocarbons, floating oils, phenolics and nitrogen compounds. Such wastes may also have a significant potential to be toxic to aquatic life, to taint the flesh of fish and to adversely affect the taste and odour of public water supplies. Fluctuations in pH and inorganic dissolved solids content can also be anticipated due to acid and alkali extraction and washing processes.

(2) ORGANIC CHEMICAL PROCESSORS

Included in this category are the major manufacturers

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of plastics, resins, polymers, synthetic rubbers and agricultural chemicals. Plants in this category are often associated with or integrated with plants in Category 1 and the nature of the waste discharges is consequently difficult to differentiate from this preceeding category.

Wastes associated with polymers and synthetic rubber manufacturers tend to be more highly organic, often including particulate organic matter such as latex crumb, while the plastics and agricultural chemicals manufacturers may discharge wastes which are more toxic due to the presence of chlorinated hydrocarbons or complex pesticide residues.

Pharmaceuticals manufacturers usually discharge wastes to municipal sewers but these will not be discussed here.

Synthetic textiles manufacturing is usually an integrated operation from the preparation of the raw material to the synthesis of the polymer. Spinning of the polymer into the textile fibre is usually a secondary operation carried out elsewhere. Wastes from the polymer manufacture are highly organic, sometimes toxic, high

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in nitrogen content (from nylon manufacture) and sometimes high in inorganic dissolved solids.

The manufacture of synthetic detergents is usually divided between the alkyl benzene manufacturers, usually the oil and petrochemical companies, and the detergent manufacturers, the soap companies. In the manufacture of the alkyl benzene the wastes produced resemble oil refinery wastes i.e. mostly cooling water with traces of oil and organics. The potential also exists for losses of acid catalyst (either sulphuric acid or hydrofluoric acid). The detergent manufacturing operation may give rise to alkaline or acidic wastes.

It is difficult to generalize about the characteristics of wastes from the manufacture of rubber chemicals and chemical specialties, except to indicate that they are often complex mixtures of trace organics which may be toxic to all forms of aquatic life. However, many of the chemical specialities manufacturing processes involve the use of generally innocuous materials so that toxic wastes cannot always be anticipated from this type of industry.

(3) INORGANIC CHEMICAL MANUFACTURING

Sulphuric acid manufacturing usually involves the use of elemental sulphur or waste sulphur dioxide as

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a raw material. Wastewaters associated with the process are mainly cooling water which may be contaminated with traces of acid.

Caustic soda and chlorine are manufactured by the electrolysis of brine in either diaphragm or mercury cells. Wastes associated with these processes include brine losses, brine treatment sludges, spent acids and traces of mercury.

Soda ash (sodium carbonate) is usually manufactured from brine by the Solvay process. Wastes associated with this process include calcium chloride, calcium sulphate, high pH and high dissolved solids content.

Fertilizer manufacturing falls into two general categories, phosphate based and nitrogen based. Phosphate based fertilizers are manufactured by acid treatment of phosphate mineral, they may be combined with nitrogenous materials in a variety of formulations. Generally, the wastes associated with this process are high in dissolved and suspended solids, phosphates and contain traces of fluorides.

Nitrogen fertilizers may be based on ammonia, ammonium nitrate, urea and to a limited degree cyanamide.

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The ammonia base fertilizers, are usually derived from the synthesis of ammonia from atmospheric nitrogen and hydrogen synthesized from natural gas. Oxidation of ammonia produces nitric acid. The wastes from these processes are cooling waters and condensates containing traces of ammonia and nitrates.

Ammonia and carbon dioxide are reacted under pressure to produce urea. Wastes associated with this process include ammonia liquors and condensates from urea crystallization and drying.

CHEMICAL MANUFACTURING WASTES DISCHARGED TO MUNICIPAL SEWERS

The general characteristics of wastes from the large capacity basic chemical manufacturers and the large capacity secondary processors are to some degree duplicated in the wastes that can be anticipated from the smaller secondary manufacturing plants discharging to municipal sewers. The wastes from these smaller plants are generally not as complex as those from corresponding large scale primary manufacturers but their indirect impact on the aquatic environment via municipal sewerage systems can be collectively just as significant.

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(1) Organic Chemical Synthesis

Small scale plants in this category are unlikely to be encountered and the discharge of wastes from such operations is not anticipated. It is worth noting, however, that aromatic solvents are handled in a wide variety of industries. They are known to be toxic to aquatic life, although they are generally biodegraded in municipal treatment systems provided the levels encountered in the raw sewage do not exceed the tolerance level of the treatment process.

(2) Organic Chemical Processing

The types of plant in this category likely to discharge wastes to municipal sewers include those plants utilizing organic chemical material in some form of secondary manufacturing.

Thus, plants processing rubber, plastics and other polymers are included. These plants generally do not constitute a problem in municipal sewage treatment since the bulk of water usage in such plants is for cooling purposes. Some plants, however, such as those processing latex, may discharge organic wastes high in suspended solids and acidity or alkalinity. These are the exception.

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Synthetic textile secondary processors also do not appear to constitute a major problem in municipal sewerage systems, although here the wastes may be high in nutrients, alkalinity, detergents and be highly coloured from dyeing operations.

Detergent manufacturing is commonly associated with the major soap companies although there are also many small scale formulators of specialty detergents and cleaners. In general the wastes from such plants may be highly organic, acidic or alkaline and exhibit acute toxicity to fish and other aquatic life. They do not however appear to adversely affect sewage treatment processes.

Agricultural chemical manufacturers discharging wastes to municipal sewers are generally small scale packagers and formulators. However, the nature of the materials handled, particularly the pesticides, poses a significant potential hazard to municipal sewerage systems arising from spills and accidents. On the other hand the manufacture, handling and sale of pesticides is subject to quite stringent federal and provincial legislation such that spills and accidents are an unusual occurrence.

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Rubber chemical manufacturing is a specialized secondary chemical manufacturing category with only one or two plants in Ontario. The wastes from such plants are highly organic and very toxic. The wastes are amenable to treatment in municipal sewerage systems but only if the system is modified to handle the wastes.

Chemical specialties manufacturers fall into the category of formulators and packagers. There is a wide diversity of chemical specialities and consequently the nature of the wastes associated with their manufacture is quite variable. Mention has been made of the detergent manufacturers, who to some degree fall into this category. Apart from the detergent manufacturers, there is little chemical manufacturing associated with the production of chemical specialties. Most of the operations are simply blending of raw materials and packaging. Therefore, potential waste discharges to municipal sewers that could arise from such plants result from equipment clean-ups or spills and accidents. In both cases the constituents of the wastes depend on what is being manufactured. It is therefore worthwhile to examine the broad nature of chemical specialities in the context of their potential effects on municipal sewerage systems:

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(a) Synthetic detergents and cleaners have been dealt with previously. They are generally biodegradable although often acutely toxic to aquatic life.

(b) Corrosion inhibitors may contain phosphates, zinc, or chromium. There are also organic and silicate formulations, although the phosphate - zinc - chromate formulations are most common. Acute toxicity is the most significant potential hazard from the discharge of these materials.

(c) Descalers are commonly acidic in nature.

(d) Defoamers may be refined hydrocarbons, petroleum distillates or silicone compounds. They are generally chemically inert and not readily degraded in municipal treatment systems.

(e) Slimicides are a broad category of toxic organic materials used for the control of fungus and other slime growths in industrial equipment. By their very nature they are likely to adversely affect sewage treatment processes although certain types are biodegradable.

Pharmaceuticals manufacturing does not generally give rise to large volumes of liquid wastes. The

nature of the operations is such that strict control of losses is necessary. No major problems have been encountered in Ontario from the discharge of pharmaceutical manufacturing wastes to municipal sewers.

(3) <u>Inorganic Chemical Manufacturing</u>

Small scale plants discharging wastes to municipal sewers are more common in this category than in the organic chemicals industry. However, there are no small scale caustic soda, chlorine or soda ash producers in Ontario discharging wastes to municipal sewers. This leaves the small sulphuric acid plants and the fertilizer producers. The small sulphuric acid producers exhibit the same problems as their larger counterparts, namely, high volume cooling waters with traces of acid loss. The small scale fertilizer producers pose a different problem, mainly from the standpoint of inadequate housekeeping and materials handling practices. Generally, these plants are essentially dry operations and water pollution problems arise from surface run-off contaminated by spilled raw materials and product. This may constitute a nutrient problem in the receiving waters.

A further category of small scale inorganic chemical manufacturing not commonly encountered in large scale operations, and, therefore, unique to municipal water

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pollution control, is the production of industrial gases such as acetylene, oxygen, carbon dioxide etc.

Of most concern is the manufacture of acetylene from calcium carbide and water. This gives rise to large quantities of calcium hydroxide sludge and a highly alkaline liquid waste. The sludge constitutes a significant solids waste disposal problem while the liquid effluent can be discharged to municipal sewers provided it is reasonably free of suspended solids. This is not always the case.

(4) Packagers and Formulators

Plants in this category have been largely dealt with under chemical specialties manufacturers. However, it is important to point out that the potential problems from waste discharges from plants in this category largely centre around the nature of the materials being formulated or packaged and the housekeeping and materials handling practices of the individual plant.

In conclusion, the general characteristics of waste discharges from the four major categories of chemical industry are summarized in Table A.

TABLE A

CLASSIFICATION	VOLUME	CHARACTERISTICS
(1) Organic Chemical Synthesis	High volume cooling waters. Low volume contaminated wastes.	High dissolved organic content. Some toxic and taste and odour producing contaminants. Floating oils and inorganic acids and alkalies.
(2) Organic Chemical Processors	High volume cooling waters. Low volume contaminated wastes.	Similar to (1). Polymers manufacturing may produce organic particulates, high nitrogen wastes and non-degradable organics. More potential for inorganic losses than (1).
(3) Inorganic Chemical Processors	High volume cooling waters. High volume contaminated wastes.	Acid or alkaline wastes from alkali producers. High suspended solids and dissolved inorganics from soda ash plants, gas producers and chlor-alkali plants.
(4) Packagers and Formulators	Low waste volume	Waste characteristics related to materials being processed. Losses may be associated with spills and poor materials handling practices. Toxicity of discharge usually of most concern.

CONDUCT OF INDUSTRIAL WASTES SURVEYS AND INSPECTIONS

If there is anything that can be consistently said about industrial wastes it is that they are not consistent. That is, they vary from industry to industry, from plant to plant and from day to day and, in order to deal with an existing or potential problem effectively, it is usually necessary to gain knowledge specific to the plant site in question.

In order to gain the specific knowledge that will complement the more general information to which you have already been exposed, it is usually necessary to carry out an industrial wastes survey - that is, to view in detail the processes and the wastes generated at an industry. In many cases, however, where considerable background knowledge is available, inspections will suffice to deal with problems, ensure compliance with regulations, etc.

For the sake of this discussion, you may assume that an inspection is usually much less comprehensive than a survey and will be tailored to the purpose for carrying it out. That is, it may or may not be carried out with prior knowledge of the industry; it may range from a visual inspection of the sewer and effluent to obtaining composite samples for analysis.

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It is the opinion of the Ministry that if you are fully aware of how to carry out an industrial wastes survey, then common sense will guide you in defining any necessary inspection program. On the basis of these assumptions then, the emphasis of the remainder of this presentation will be placed on matters related to conducting an industrial waste survey.

Basically speaking, the purpose of an industrial wastes survey is to determine the nature and volume of wastes emanating from a plant while taking into account variations in flow rates, in strength and in characteristics of batch dumps, etc. To achieve this goal, it is suggested that the survey be approached in three parts; pre-field survey work, field survey work and post-field survey work.

PRE-FIELD SURVEY WORK

The amount of pre-field survey work required will vary and depend largely on the degree of familiarity the surveyor has with the type of industry and the plant in question, and on the size and complexity of the operation(s). Before visiting the plant, the surveyor should draw on local sources such as the Industrial Commission and the Public Utilities Commission to learn as much as he can

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about the plant's activities. Having determined in general terms, the nature of the Company's activities, the surveyor can then refer to technical literature for more detail, particularly with respect to water use and waste production.

As a first approach, reference should be made to a text covering manufacturing processes, etc., at the type of industry in question. Such texts which might apply, include "The Chemical Process Industries" by R.N. Shreve, "Electrofinishing" by M. A. Brimi and J. R. Lock, "Electroplating Engineering Handbook" edited by A. K. Graham and "Modern Dairy Products" by L. M. Lampert. (A more complete reference list for industrial waste studies is provided in the Appendix). Based on material and bibliographies contained in the texts, reference can then be made to technical journals, conference proceedings (e.g. Purdue and Ontario Industrial Waste Conferences)and other references to gain more knowledge of the process operations, nature and volume of wastes to be expected, etc. In this way, a good working knowledge of the industry can be obtained, and when personal contact with plant management is made, appropriate questions can be asked and all relevant data collected with a minimum of confusion, repeated visits, and the like.

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FIELD SURVEY WORK

Armed with that type of knowledge, the surveyor then makes contact with management of the industry in question. It should be emphasized that contact must be made with management at a decision-making level and that, throughout the survey, the surveyor must be able to refer questions to people, preferably one man, fully familiar with technical matters within the plant. If at all possible, do not waste your time dealing with the chap who parks the chief's car.

On initial contact, you should explain carefully to management the purpose of your visit, the reason it is necessary, and ask for full cooperation. Having obtained their attention, and hopefully their cooperation, you can then commence with your survey by obtaining data specific to the plant in question.

Operating data obtained should include a description of raw materials, catalysts, etc., used and intermediate and final products produced as these are the materials which may appear in the waste discharge. In addition, you should note production rates, the amount and source of water used, the plant operating schedule and the number of employees on site.

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Then, with management and/or plant technical staff, the distribution of water within the plant should be established and production processes reviewed. Any processes utilizing water should be examined in detail, particularly where water is contacted with raw materials, products, etc., and the nature, volume and point of discharge of the wastes from these processes should be clearly established. In this regard, frequent reference to up-to-date sewer maps and plant lay-out maps will prove invaluable and you should attempt to obtain copies of these from the Company management.

Processes which may result in spills or in batch dumps of spent solutions, etc., should receive close scrutiny since such discharges can have severe adverse effects on a municipal system if not handled properly. Such discharges are <u>not always associated with water use</u>.

During the review of processes, an effort should be made to carry out a mass balance on materials arriving at and leaving the plant by conventional means as the difference will often given a close approximation of the quantity and type of air and water-borne wastes.

As the review of the processes proceeds, it should become clear where it will be necessary to carry out

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sampling and measure flows to establish the characteristics of the wastes. This should be confirmed with a tour of the plant during which the surveyor should be most observant, noting general housekeeping conditions, sources of waste which may have been overlooked during previous discussions, discrepancies in sewer lay-outs, etc. In some cases, it may be necessary to carry out dye tracing studies to confirm or check sewer systems.

Procedures for sampling and flow measurement will be the subjects of two other papers, but some reference should be made to these aspects of the survey at this time.

First, although municipal by-laws usually deal in concentrations of waste parameters only, we are often quite concerned with the total loadings in pounds per day of a particular component. In order that these data should be meaningful, we must obtain <u>representative samples</u> of the waste flow under consideration and <u>accurate flow data over the period of sampling</u>. Without such data, at the best, you will be extremely lucky if you can discuss the waste disposal situation intelligently, and at the worst, large sums of money could be wasted on needless or inappropriate treatment facilities, legal

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proceedings could prove to be embarrassing to the municipality and non-equitable sharing of municipal waste treatment costs could occur. Thus, good common sense must prevail when it comes to sampling and flow measuring.

In many situations, existing public utility water meters and manual sampling may provide the necessary data, but in more complex situations (i.e. several outfalls and variable flows) more sophisticated equipment or techniques may be necessary, such as automatic samplers which sample proportional to flow, portable weirs and equipment for flow measurement by salt dilution techniques. In other situations, it may be advisable to have the Company install permanent sampling and flow measurement and recording equipment, particularly where industrial waste surcharges may be assessed. Also at this point, do not overlook the benefits of having your own portable monitoring and recording equipment available for installation in sewers for short or long term periods (e.g. pH and conductivity probes). These are also very useful inspection and enforcement tools.

The degree to which one must go to obtain samples and flow measurements or estimates, will depend largely

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on the purpose of the survey. Often an order of magnitude is all that is required (i.e for routine surveillance) and in these cases, simple techniques will do. On the other hand, if by-law enforcement, industrial waste surcharge calculations, treatment facility design, etc., are factors under consideration, then data must be very reliable.

It is essential to note that in addition to requiring knowledge of hour-to-hour variations in waste characteristics and flows, it is eoually important to be aware of day-to-day, week-to-week or seasonal variations which may occur. For example, establishing the nature and volume of wastes at a canning factory when peas are being processed in June will be of little value in assessing the situation in August and September when corn and/or tomatoes are being processed. The examples here are endless and this is one reason why pre-field survey work can be so critical to obtaining and putting together the total picture.

Once sampling locations have been established and appropriate samples and flow data have been obtained, it is then necessary to have the samples analyzed in a reliable laboratory with due concern given to the potential for decomposition before analysis can be performed.

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In some cases, preservation of samples with appropriate chemicals may be necessary (i.e. phenol, sulphides and cyanide-bearing samples should be preserved), in other cases, refrigeration of samples is desirable, and in all cases there should be a minimum of delay between sampling and analysis. Dialogue between the laboratory staff and survey personnel prior to sampling can prove most useful in this area.

POST-FIELD SURVEY WORK

Having returned to the office with the information obtained from the industrial representatives and having received the analytical data from the laboratory, an assessment of the data can now be made and, in most cases a report written. It is suggested that a standard report format be prepared and followed in every case so that important items are not overlooked. The format generally followed by the Industrial Wastes Branch of the Ministry of the Environment is shown in Figure I. It is also recommended that the report be prepared as soon as possible after completion of the survey.

In reviewing the material, the analytical data should be examined carefully to see if the results are consistent with visual observations and anticipated results.

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FIGURE I

REPORT FORMAT

Introductory Paragraph (No Heading)

SUMMARY (Caps

DETAILS OF SURVEY (Caps)

Introductory Paragraph (No Heading) - with date, time, etc.

Personnel Participating

Personnel Interviewed

Description of Plant and/or Process(es)

Production and Operating Data

Water Consumption and Distribution

Sources of Liquid Wastes, Treatment and Disposal

Sampling and Analysis

WASTE LOADINGS AND PRODUCTION RELATIONS (Caps)

DISCUSSION OF FINDINGS (Caps)

CONCLUSIONS, REMARKS AND RECOMMENDATIONS (Caps)

(Initials of typist and author) Signatures

REFERENCES (Caps)

APPENDICES
(Centred and Caps)

These results can be cross-checked on the basis of expected waste loading to production ratios, material balances, volume of water used, etc. If the data do not appear reliable, repeat analysis may be advisable or in some cases, it may be necessary to obtain more samples. There have been situations where initial indications were that a Company was discharging more material to a watercourse than it received at the plant site. Usually a reasonable explanation of such results can be found and it is not always the fault of the flow measurement and sampling techniques used.

When the surveyor is satisfied that his data are reliable, he must then compile and interpret it. He then commits to paper a discussion of the results, his visual observations, etc., and outlines his conclusions and recommendations. In some cases the report may be very short and in others very much larger, depending on the purpose of the survey, the complexity and size of the industry and the degree of waste control already provided.

As a final comment, although somewhat removed from this topic, it should be pointed out that all of the preceding work may be of no consequence unless active follow-up on recommendations is carried out. Inspections

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or surveillance visits prove most useful at this stage and remind the industry that they have not been forgotten.

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SAMPLING

The object of this paper is not to present a complete and definitive statement of sampling procedures and equipment and it is suggested that you treat with a measure of scepticism anyone who claims to have all the answers to the problems posed in connection with sampling. In effect, there are no standard answers, there can be no dogma and probably the only statement on the subject which can be made without risk of contradiction is that the sampling portion of each survey will involve a set of circumstances which render it unique. To those who may feel that this approach to the subject is somewhat generalized and simplistic, it must be pointed out that the subject itself is generalized and simplistic unless specific cases are considered and these, of course, except for a very few examples, are beyond the scope of this short presentation.

Now if it appears that this approach denies the existence of absolute expertise in the methods and procedures of sampling, the purpose has been to encourage the use of ingenuity and improvisation when faced with actual situations in the field and to guide away from any attempt to use "standard" techniques during surveys which inevitably are far from being open to such treatment. However, the impression should not

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be left that there are no rules of procedure or that sampling techniques are purely empirical. They are not. In fact there are very well defined basic considerations that must be dealt with.

BASIC CONSIDERATIONS

(1) Representivity and Uncertainty

Reflect for a few moments upon the meaning and implication of the word "sample". As a noun the word may be taken to mean; "a portion or part taken as representative of the whole". This is a simple definition but its importance cannot be overstressed, since every procedure of sampling is aimed toward the highest degree of representativity which can be obtained. To illustrate this principle, consider that it is desired to know the quality of the water in a lake. To be completely certain that the sample taken is representative of the whole body of water, it would be necessary to take as the sample every drop of water in the lake. Now this obviously is not practical and a much smaller quantity of water must serve as our sample. This being so, it can be less certain that the sample is representative of the whole, and the task in sampling, therefore, is to carry out the work in a manner which will minimize the uncertainty. In the case of the lake, it can be done by sampling the water at many points throughout the whole mass; the greater the number of samples, the greater the certainty that a representative portion is obtained.

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Most probably you will never be called upon to sample a lake, but you will, no doubt, at some time be required to determine by sampling whether a particular discharge violates a by-law. Since legal proceedings may follow from your work, the representivity of your samples must be as certain as technology will allow and your methods and procedures in obtaining the samples must reflect this. It cannot be overstressed, therefore, that at all times you must consider whether the methods you are employing will result in the fulfillment of the objectives of the survey - with the smallest possible degree of uncertainty.

(2) Pre-sampling Steps

The data collected during the sampling portion of a survey may be used to serve a variety of purposes and since the procedures used to obtain these data will vary with the contemplated use of the findings, the first step in planning the work is to review the objectives of the survey. For example, if it is decided that the prime purpose of the survey is to determine the quantity of a pollutant being discharged during a twenty-four hour processing day, there is little point in taking a single grab sample. Suppose that the waste stream has a concentration of pollutant of 10 lbs. per gallon at the instant the sample is taken and this persists for one hour, but for the remainder

of the twenty-four hours it increases to 20 lbs. per gallon. A simple calculation will demonstrate the gross inaccuracy of that single grab sample:

Suppose the flow rate is constant at 100 gallons per hour, then the quantity of pollutant discharged in twenty-four hours (based on the grab sample) would be:

24 hours x 100 gallons per hour x 10 lbs. per gallon =
24,000 lbs.

However, it is known that the concentration is 10 lbs. per gallon only for one hour and is 20 lbs. per gallon for 23 hours. Therefore, the correct loading would be:

1 hour x 100 gallons per hour x 10 lbs. per gallon =
1,000 lbs.

\+ 23 hours x 100 gallons per hour x 20 lbs. per gallon =
46,000 lbs.

The Total for twenty-four hours would therefore be
47,000 lbs.

Therefore, by basing the calculation on one single grab sample, the result is in error by 23,000 lbs. That is, the true quantity of pollutant is almost

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double that found by sampling. This is a very simple (and exaggerated) example, but it does illustrate the principle involved. In this case, the concentration of pollutant obtained from a single grab sample, when applied to the whole twenty-four hour period, produces an uncertainty in the calculated quantity of pollutant which is so great that the result is meaningless. The object during a survey is to reduce this uncertainty to a tolerable level.

The second pre-sampling step is to observe the process or processes which give rise to the waste stream. This observation should also include a preliminary measurement of flow rates and their variation during the processing period and even, in certain cases, preliminary sampling of the waste. For example, if the process is one in which there are periodic dumps of high-volume, high-strength material, it would not be advisable to combine aliquots taken at intervals to form a single large sample.

Thirdly, the determination of the points at which the samples will be taken must be made, and for this use should be made of sewer diagrams to ensure that the chosen points will provide data consistent with the objectives of the survey. To illustrate this, if

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the objective is to determine the relative contribution of two process streams which are confluent, at least one sampling point must be upstream of the confluence. An important consideration following from this is that a sample taken downstream of the confluence should be taken sufficiently far downstream to ensure that complete mixing has taken place.

Having carried out the above steps, in greater or lesser detail depending on the needs of a particular survey, you will be in a position to delineate the number and location of sampling points, the type of samples, the frequency of sampling, the duration of the sampling period, the analyses required and any other pertinent factors such as, for example, manpower and equipment requirements.

Now you may feel that you have not been provided with sufficient guidance actually in making these decisions, but these matters form the subjects of two other lectures from which you will draw adequate information. These will not therefore be pursued further here.

(3) Other Considerations

The means by which samples may be obtained are

many and varied. The particular technique and equipment to be used in a given case will depend on factors such as the characteristics of the waste stream, the location of the sampling point, the type of sampling point, the type and size of the sample, the interval between aliquots of a composite sample and the duration of the sampling period. Other considerations are, the number of sampling points, the distance between sampling points and the availability of survey personnel.

Consider each of these:

(a) Characteristics of the Waste Stream

Account must be taken of the velocity of the flow, the presence of floating liquids such as oil, the presence of heavy suspended solid material which may form a layer on the bottom of the sewer and the presence of heavy liquids upon which the water may float.

As an example of the need for carefully choosing the sampling technique, suppose that a sample is to be taken from a waste stream upon which oil is floating. If the sample container is filled below the surface, no oil will be included and an entirely false picture of the quality of the wastewater will result. If, however, the sample container is filled at the surface, an unrepresentative quantity of oil may be included,

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again with unsatisfactory results. In this case, the only sure way of obtaining a representative sample would be to ensure that the whole cross-section of the flow enters the sample container. Where this cannot be achieved, or where the waste stream cannot be homogenised (for example, by extreme turbulence) you may be forced to resortto more exotic and less certain methods. You will then, of course, place less reliance upon the results.

The above example illustrates the need to adjust the method of sampling to suit the characteristics of the waste stream, but it is equally important that the correct equipment be used. In the case of a waste stream of high velocity, a light metal or plastic sample container on a rope is virtually useless. Or, if a sample is to be obtained at a given depth, some means must be provided to ensure that the closed sample container may be opened when the desired depth is reached. It is quite useless, in another case, to attempt to sample a thick oil floating on water by using a narrow-necked bottle as the sampling device.

To summarize, the characteristics of the waste stream must be carefully observed,the possible effects of these characteristics on the objectives of the survey

must be considered and the methods and equipment used in sampling must be carefully chosen to eliminate errors and reduce uncertainty in the final result.

(b) Location of the Sampling Point

The location of the sampling point is an important matter in obtaining a proper result. It has already been stated that where two streams are confluent, the sampling point must be sufficiently far downstream to ensure that the two streams are completely mixed when sampled. In certain cases, especially where the streams are large and slow-moving, complete mixing may not be achieved for a considerable distance. If this is suspected, a dye may be added to one stream so that the point of complete mixing may be determined. In another situation, where the sampling point is in a fairly large open channel, the sample should not be taken at the surface, nor at the bottom,nor at the sides. Rather, the flow should be sampled in the middle of the channel and at approximately one-third of the depth. It can be shown that this will provide the most representative sample. To generalize, what this means is that sampling points must be established where the waste stream is as homogeneous as possible. Other locations where it may not be homogeneous are, immediately above a weir, immediately below a weir, immediately downstream of a sharp bend in a large sewer, etc. Careful

observation of on-site conditions is essential if errors due to non-homogeneity are to be avoided.

(c) Type of Sampling Point

The method of sampling and the equipment to be used will also depend upon the type of sampling point. For example, the technique and apparatus needed to obtain a sample from a small, deep manhole will be quite different from those required to obtain a sample from the centre of the volume of liquid contained in a large tank. Again, as before, your efforts must be directed toward obtaining a sample as representative of the whole as possible. As an illustration of a simple technique, when sampling from a valve on a pipe, the liquid should be allowed to run to waste for a few seconds before taking the sample to ensure that the escaping liquid is of the same quality as that flowing in the pipe at the time of sampling.

(d) Type and Size of Sample

These considerations are quite straightforward and involve mainly the correct choice of equipment.

(e) The Interval Between Aliquots of a composite sample, the duration of the sampling period, the number of sampling points, the distance between sampling points and the availability of survey personnel all will affect your technique and your choice of equipment. Examples

will not be given since the principles involved are specific to each case. They are, however, matters of common sense and should present no difficulty in the field.

TYPES OF SAMPLES

(a) Grab Samples

As the name implies, a grab sample is an aliquot taken in a single excursion of the sampling device into the flow being sampled. The volume taken is determined only by the requirements of the analytical procedures to be carried out on the sample and no account need be taken of the flow rate at the time of sampling. A grab sample is useful in determining the characteristics of a waste flow at a specific time, but not very useful for calculating a waste loading since a single aliquot is infrequently representative of average conditions. Its application, therefore, is generally restricted to those cases where concentration limits apply.

(b) Composite Samples

A composite sample is one which is built-up or "composited" from a series of grab samples taken at intervals during the sampling period.

This type of sample represents the average characteristics of the waste flow over the survey period and

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in conjunction with the flow volume over the same period may be used to calculate waste loadings.

Composite samples are of two types;

(1) those in which the grab samples are kept separate and analysed separately, and

(2) those in which the grab samples are combined together to form a bulk sample, all or part of which is subjected to analysis.

Both types enable the average characteristics of the waste flow to be determined, but the first type also enables the variations to be clearly seen.

In the first type, a constant volume is taken at each interval regardless of the flow rate at that time. However, if a waste loading is to be calculated and it is known that the flow rate is not constant, a measurement of the flow rate must be made when each sample is taken.

In the second type of composite, where the aliquots are combined, a constant volume is taken at each interval only when it is known that the flow rate is constant. Where the flow rate is variable (as in most industrial processes), the volume of the aliquot

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taken at each interval must be in proportion to the flow rate at the time when the sample is withdrawn from the waste stream. For example, if at one sampling time the flow rate is measured and found to be 100 gpm and an aliquot of 500 mls is taken, at the next sampling only 100 mls should be taken if the measured flow rate is 20 gpm.

A constant time interval is usually chosen between aliquots of a composite sample, since most variations in waste characteristics occur on a time cycle. However, in certain cases variations may occur on a volume basis and the sample aliquots would then be taken at volume intervals, e.g. one sample for each 1,000 gallons of flow.

The intervals between aliquots are determined by the variability of the waste characteristics. If the characteristics vary rapidly, the aliquots must be taken frequently, while if the waste is of fairly uniform character, the intervals may be longer. The most accurate average will of course be given by a continuously drawn sample, but unless automatic equipment is used, this will be impractical. Therefore, longer intervals, such as 10, 15 or 30 minutes are

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often used. However, in no case should aliquots be taken less frequently than once per hour. A similar principle applies in the case of variation of characteristics with volume.

METHODS OF SAMPLING

The methods available are of two types, automatic and manual and the following are examples of each with their advantages and limitations:

(a) Automatic

(1) Vacuum Sampler

This apparatus, shown in Fig. I, consists of an evacuated sample container, fitted with an electrically (or mechanically) operated stopcock and a length of tubing. The open end of the tube is placed in the waste stream and the stopcock opening mechanism is set to operate at the required intervals. When the stopcock opens, the sample is drawn into the container by the vacuum. The open period of the stopcock is set to give the required aliquot volume. In this simple form, only the "bulked" type of composite sample can be taken, but a variation of the equipment may be used in which a number of small bottles each being evacuated and each having a stopcock and sampling tube is arranged so that each stopcock may be opened in correct sequence, and at the proper interval, by a timing mechanism.

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This allows the collection of separate aliquots which are kept separate for analysis. Advantages of this type of apparatus include simplicity, low cost and ability to function for long periods on a small storage battery. Its chief limitations are that it must be used only with a short tube and that, for the greatest accuracy, it should be provided with a stopcock which will vent the tube to atmosphere between aliquots, thereby allowing the tube to drain before the next aliquot is taken.

(2) Pump Sampler

As the name inplies, this type of sampler consists of a pump which transfers the sample from the waste stream to the sample container via a tube. A simple form is shown in Fig. II. As in the previous example, a timing mechanism may be used to control the intervals between aliquots and the size of the aliquots taken. Many types of pumps may be used, amongst the most useful being chemical feed pumps, due to their ability to dispense small, accurately measured volumes of liquid.

A modification of the basic pump sampler is one in which the pump runs continuously, pumping the liquid from the sampling point, through the sampler and out to waste. At the proper intervals the desired quantity of liquid is withdrawn by a mechanical arrangement which diverts into the sample container all or part of the

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flow through the machine. Examples of such are shown in Figs. III, IV and V.

In addition to the above modification, it can be arranged, as in the case of the vacuum sampler, that a number of small sample containers be filled rather than a single large container, depending on the type of composite sample required. Advantages of this type of sampler include simplicity, relatively low cost and ability to function on a small battery. As with vacuum samplers, they are limited by the necessity of using only a short tube (preferably vented to atmosphere between aliquots) or by having a continuous flow through the machine.

(3) <u>Scoops and Wheels</u>

In addition to those samplers which work either by vacuum or by pumping, there are many other types which are based on various arrangements of wheels, discs and rotating scoops. An example of these is shown in Fig. VI. Again it should be kept in mind that all types have advantages and disadvantages which should be considered before a selection is made for a particular survey.

(4) <u>Instruments</u>

Although some may not feel that instruments are sampling devices, it is proposed that, for

example, the use of a thermometer to measure the temperature of a stream is a legitimate sampling technique. Any consideration of automatic sampling devices should include, therefore, thermometers, turbidity meters, pH meters, oxidation-reduction potential meters, hydrometers, conductivity meters, and so on. These are useful sampling tools and should be used whenever necessary.

(b) Manual

Equipment used in manual sampling is quite simple, consisting usually of a mechanical extension of the hand and arm. A manual sampling "kit" should consist of buckets of various sizes and types, lines, poles (able to be joined together), bucket or bottle holders and weights. Advantages of manual sampling include almost complete reliability and power of observation and decision. Its chief limitation is very high operating cost.

ANALYTICAL CONSIDERATIONS

(a) Selection of Sample Volume

In general, the largest practical sample volume should be taken but in no case should the amount taken be less than 120% of the volume required for the analyses

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to be performed. The surplus allows repeat analyses to be carried out if necessary. Table A shows the sample volumes required for various analyses. Please bear in mind that these are based on the methods of analysis carried out by the Ministry laboratories.

(b) Selection of Sample Container

Glass or plastic containers are generally acceptable for the common run of samples which are encountered. Where a sample will be analysed for metals, a plastic container preferably should be used since certain metals tend to "plate" out on glass bottles. For most other elements, however, a glass container is suitable, but it should be carefully noted that if the cap has a foil liner it must be removed and replaced with a piece of plastic film should the bottle be used for a sample to be analysed for metals. Whatever container is used, it must, of course, be chemically clean.

(c) Transfer of Sample

When transferring a sample from the sampling device to the container, care should be taken to avoid spillage and in this respect a small funnel may be helpful. The minimum delay should be aimed for in transferring the sample and it is important also that the whole volume of the aliquot taken should be placed in the sample container. This is especially important in

the case of an aliquot which contains suspended solid or liquid matter, where, if only a portion is transferred to the container, an unrepresentative amount of the suspended matter may be left in the discarded portion. The sampling device should, therefore, be of a size which will allow use of the whole aliquot.

(d) Perishability of Samples

Ideally, all samples should be subjected to analysis as soon as possible after collection. Where this cannot be done, the samples should be preserved to prevent deterioration. All samples are more or less perishable, bacteriological and biological samples being the most critical. In fact, these samples, in collection and handling, are so specialized that no previous mention of them has been made. It is suggested, if these types of samples must be taken, that you seek expert advice prior to sampling. Samples for chemical analysis are less sensitive, although certain parameters such as dissolved gases and temperature are very unstable and must be analysed for in the field. All samples should be kept cool, especially those to be tested for BOD. In Table A you will find a list of preservatives which may be used. You must bear in mind, however, that if a preservative is added to a sample, it may interfere with analyses for substances other than

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the one preserved. Therefore, if more than one test is to be carried out on a sample, two aliquots should be taken and preservative should be added only to one. Remeber that samples should be protected from freezing, as this often alters certain characteristics.

(e) <u>Identification of Samples</u>

It is, of course, of the utmost importance that samples be properly and accurately labelled or otherwise marked to permit identification. The information required for each sample consists of:

(1) Location of survey; municipality; name of Company.
(2) Date
(3) Location of sampling point.
(4) Type of sample.
(5) Duration of sampling period.
(6) Time at which a grab sample is taken.
(7) Intervals between aliquots of a bulked composite sample.
(8) Nature and quantity of added preservatives.
(9) Name of sampling personnel.
(10) Container number.

This information should be recorded both on the bottle and in the field notebook. The container number should

be marked at several places on the bottle, not only on an attached label, in which case the sample may be identified if the label is inadvertently removed. Please note that the bottle should be clearly marked if it is suspected that there is a high concentration of toxic material in the sample. This will alert the analyst and avoid accidents in the laboratory.

SAFETY IN SAMPLING

It is a fair statement that no sample is worth obtaining at the risk of life and limb.

Physical safety is for most of us a matter of instinct in our ordinary daily routine, but in unusual situations, such as may be experienced in survey work, we may not recognize actual or potential danger. Also, however trite it may be, it is true that familiarity often breeds contempt, sometimes with tragic results.

The following are a few observations on personnel safety:

(1) When sampling from a boat, a life jacket must be worn at all times.

(2) When sampling from a river bank, it must be quite certain that the bank is stable

and not eroded.

(3) Never sample alone at night.

(4) Never enter a tank or other vessel or a sewer unless it is unavoidable, and then only when it is known that the atmosphere is free of noxious gases and there is no possibility of any material entering while sampling is in progress. Such a procedure must not be carried out alone and a life line must be used.

(5) Always remember that most organic liquids are highly inflammable and form explosive mixtures with air. Smoke only in safe places.

(6) All chemical substances must be regarded as noxious (until otherwise proven) if ingested into the stomach or lungs, or by contact with the skin and eyes. It is vital to know what materials may be encountered during a survey and to use all necessary protective devices.

In conclusion, it may be stated that application of the general principles outlined above, combined with inventiveness and initiative in the field, will result in the most representative samples and will ensure proper

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control of industrial wastes in accordance with the terms of sewer-use by-laws.

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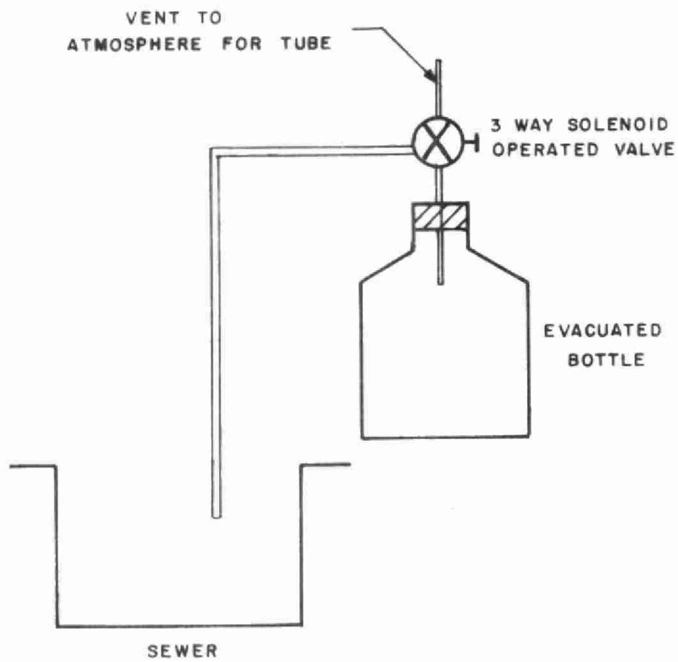
FIGURE I

VACUUM SAMPLER



TUBE IS VENTED TO ALLOW DRAINAGE BETWEEN ALIQUOTS

FIGURE II

PUMP SAMPLER

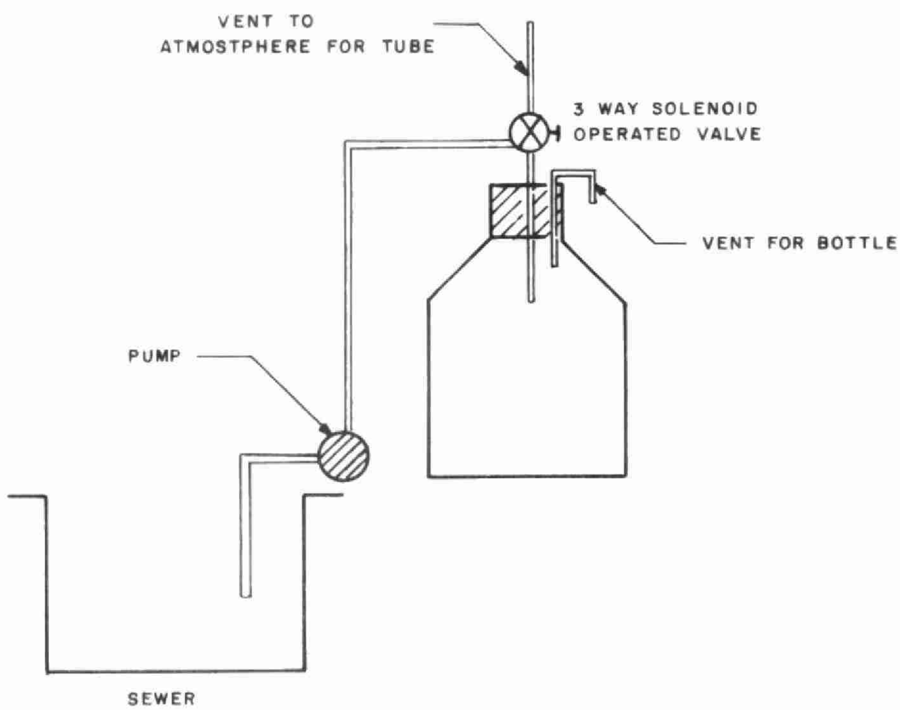
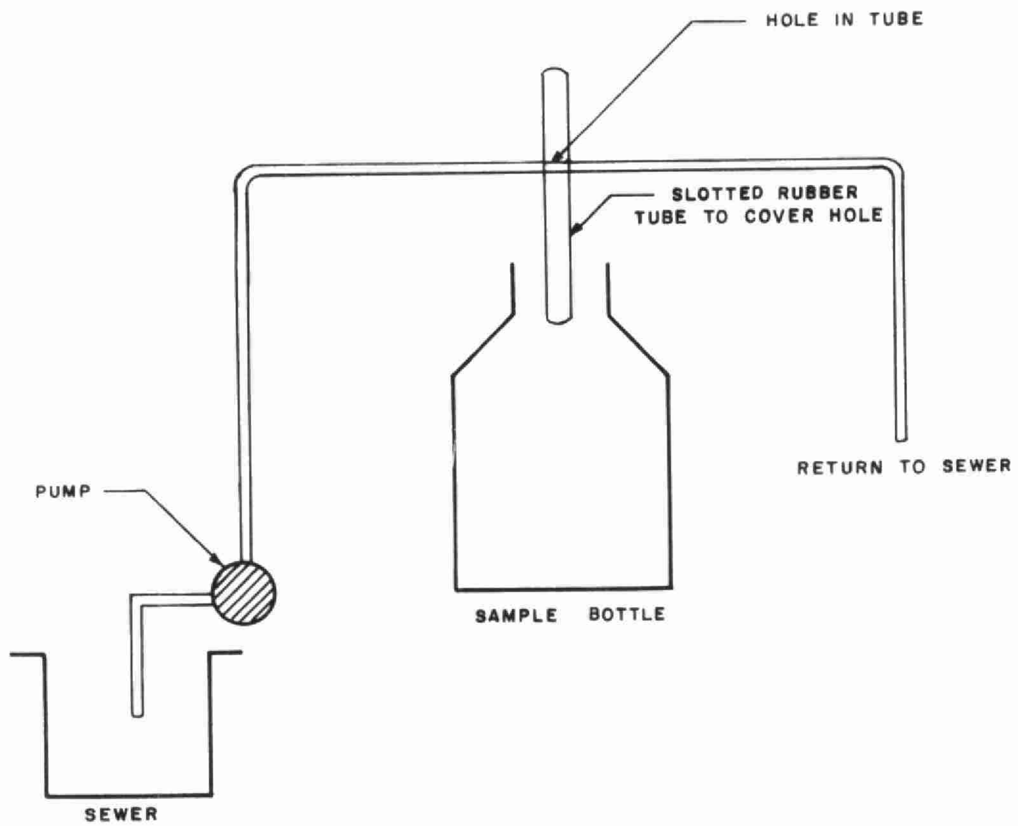


FIGURE III

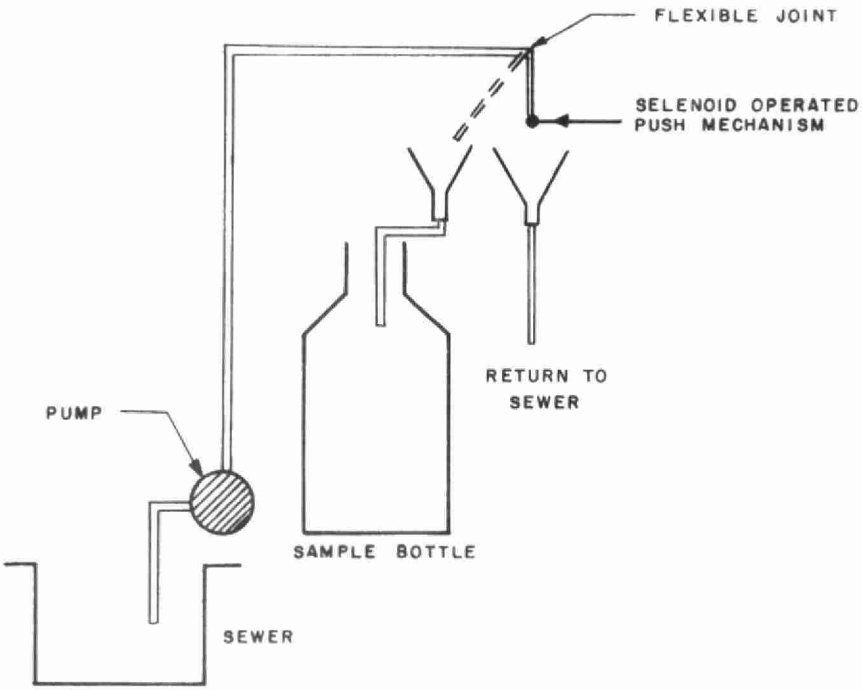
DRIP TUBE DIVERTER



FLUID LEAKS FROM HOLE IN TUBE AND FLOWS VIA DRIP TUBE (SLOTTED RUBBER TUBE) INTO SAMPLE BOTTLE

FIGURE IV

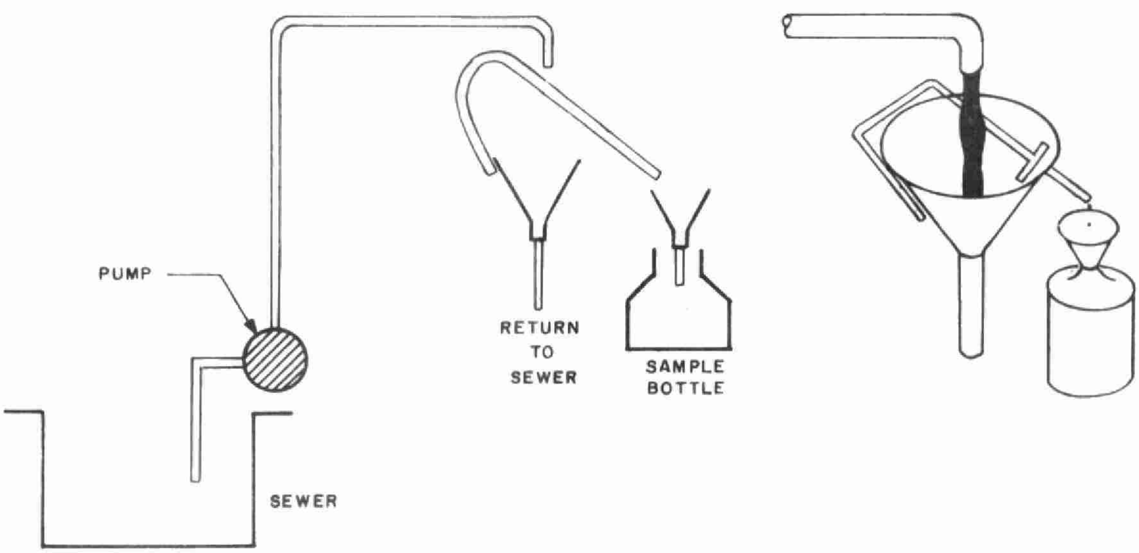
SOLENOID DIVERTER



SOLENOID PUSHES TUBE OVER TO FUNNEL LEADING TO SAMPLE BOTTLE

FIGURE V

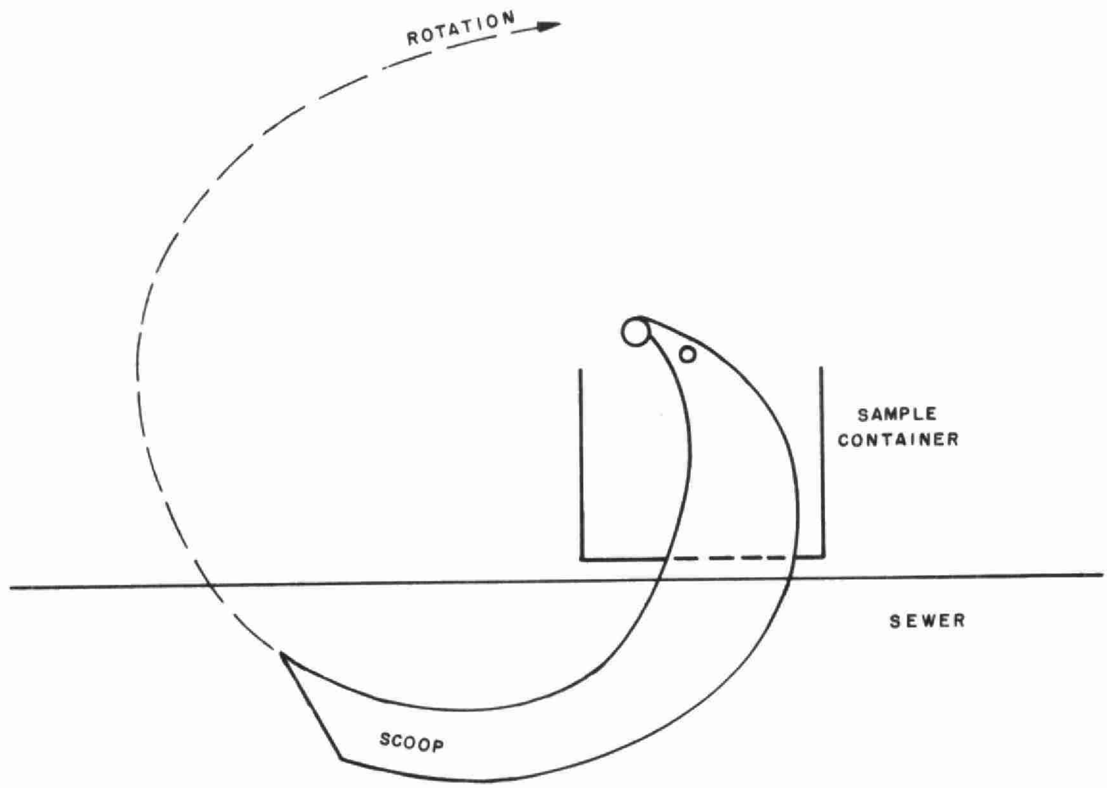
FUNNEL AND ROD DIVERTER



WIRE ROD PASSES THROUGH FLOW AND CAUSES A SMALL QUANTITY OF LIQUID TO FLOW DOWN IT INTO THE SAMPLE BOTTLE

FIGURE VI

ROTATING SCOOP



THIS SCOOP IS SHAPED IN SUCH A WAY THAT THE QUANTITY TAKEN AT EACH ROTATION IS PROPORTIONAL TO THE LIQUID LEVEL ie PROPORTIONAL TO THE FLOW

AS THE SCOOP ROTATES TO ITS UPPER POSITION THE LIQUID FLOWS TO THE HUB WHERE IT IS DISCHARGED INTO THE SAMPLE CONTAINER

TABLE A

ANALYSIS	VOLUME REQUIRED (ml)	CONTAINER REQUIRED	PRESERVATIVE REQUIRED
Alkalinity	75	G or P	None
Aluminum	100	G^1 or P	None
Ammonia	75	G	H_2SO_4
Anionic Detergents	125	G	None
Antimony	400	G or P	None
Arsenic	50	G^1 or P	$None^2$
Barium	50	G or P	None
BOD	500	G or P	Refrigerate
Boron	100	P	None
Cadmium	100	P^1	HNO_3
Calcium	100	P^1	HNO_3
Chloride	400	G or P	None
Chromium	100	G or P	None
Cobalt	100	P^1	HNO_3
COD	75	G	None
Conductivity	200	G or P	None
Copper	100	P^1	HNO_3
Cyanide	500	P	NaOH
Fluoride	350	P	None
Hardness	75	G or P	None
Iron	100	P^1	HNO_3
Lead	100	P^1	HNO_3
Lithium	100	P	None
Magnesium	100	P^1	HNO_3
Manganese	100	P^1	HNO_3
Mercury	500	G^1	H_2SO_4 + $KMnO_4$
Molybdenum	200	P	HNO_3
Nickel	100	P^1	HNO_3
Nitrate	75	G or P	None
Nitrite	75	G or P	None
Nitrogen (Kjeldahl)	75	G or P	None
pH	25	G or P	None

Note: G = Glass
P = Plastic

Contd.........

ANALYSIS	VOLUME REQUIRED (ml)	CONTAINER REQUIRED	PRESERVATIVE REQUIRED
Phenols	?[3]	G[4]	$H_2SO_4 + CuSO_4$
Phosphorus	75	G or P	None
Potassium	75	G or P	None
Selenium	500	G[1] or P	None
Silica	100	P	None[2]
Silver	100	P[1]	HNO_3
Sodium	75	G or P	None
Solids	500	G or P	None
Sulphate	250	G or P	None
Sulphide	50	G	$ZnC_2H_3O_2$ + NaOH
Tin	100	G or P[1]	None
Titanium	100	G or P[1]	None
Turbidity	150	G or P	None
Uranium	10	P	None
Vanadium	100	G or P	None
Zinc	100	P[1]	HNO_3
Organic analyses	?[3]	G[4]	None

1. - if plastic is not available, glass bottles may be used only if the foil cap liner is removed and replaced by plastic and the sample preserved.

2. - it is essential that no nitric acid be used.

3. - as large a sample as practical.

4. - plastic must not be used and glass bottles must have foil lined caps.

NOTE:

(a) HNO_3 = nitric acid (concentrated). Add 10 drops to each bottle and mix well.

(b) NaOH = sodium hydroxide (caustic soda). Add two pellets to each bottle.

(c) $ZnC_2H_3O_2$ = zinc acetate. Add sufficient to form a good precipitate; ensure that there is excess sodium hydroxide present.

(d) H_2SO_4 = sulphuric acid (50% solution). Add 10 drops to each bottle.

Contd......

(e) $KMnO_4$ = potassium permanganate (saturated solution). Add sufficient to maintain a purple colour.

(f) Cadmium, Calcium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Nickel, Silver and Zinc may all be determined on a single 400 ml sample.

(g) A 150 ml sample is required if both total and soluble phosphorus analyses are required.

(h) Total phosphorus and kjeldahl nitrogen may be determined on the same 75 ml sample.

(i) Soluble phosphorus, ammonia, nitrate and nitrite may be determined on the same 75 ml sample.

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FLOW MEASUREMENT

INTRODUCTION

The measurement of the volume of liquid effluents being discharged by an industrial complex is probably the most important aspect of any industrial plant survey. Where discharges are to municipal sewer systems it is necessary to know the volume of discharge to enable the loadings of suspended solids, BOD_5, etc., to be calculated. These loadings are required for sewer system design, surcharge calculations and by-law enforcement. In addition, it is usually beneficial for a company to know the magnitude of its process losses as cost savings can frequently accrue from minor changes in process once the source of a loss is known.

It is often necessary in an industrial establishment to obtain a water balance and process material balance to determine the efficiency of a particular process unit or waste treatment facility. Such balances are only possible with accurate flow measurement.

Finally, in cases where discharges are made to natural watercourses, the volume and loadings of waste components must be known to evaluate resultant stream conditions and to determine whether the requirements of pollution abatement agencies are being met.

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Only liquids exerting "Newtonian Flow" (water-type) will be considered here. Slurries and thixotropic fluids are outside the scope of this presentation.

GENERAL

In an industrial plant, liquid wastes are conveyed to a sewer or discharged from the building in one of two ways:-

(a) closed conduit or pipe

(b) open channel or ditch.

Generally, different types of measuring devices are required to measure the flow in the two cases although some devices are applicable to each. Both the closed conduit and the open channel will be encountered in industrial plants during the course of your work and a knowledge of the types of measuring device most frequently in use will be beneficial. The majority of flow measuring devices require permanent installation but some are portable and can be used to great advantage during a plant survey, particularly as a check against installed equipment.

(A) FLOW MEASUREMENT IN CLOSED CONDUITS OR PIPES

(1) Bucket - Stop Watch

This time-honoured method is still used extensively and provides one of the most convenient methods of

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measuring flow providing the open end of the pipe is accessible and providing a bucket can be conveniently placed under the open end to catch the discharging liquid. The only guidelines to the use of this method are that the bucket or container should be large enough to ensure that a reasonable time period elapses during filling. 30 - 60 seconds are generally adequate, although a larger container requiring more time to fill should be used if greater accuracy is required. Also, the measurement should be made three or four times and the results averaged for greater reliability.

This method is particularly useful for smaller effluent volumes and for calibrating other flow measuring devices.

(2) Open-End Pipe Discharge

The distance to which water jets out from an open-end horizontal pipe is a function of the flow of water existing in the pipe. A system of co-ordinates can be established (Fig. I) and the following equation can be used:

$$Q = \frac{1500\ A.X.}{\sqrt{Y}}$$

where Q = volumetric discharge in imperial gallons per minute (I gpm).

A = cross sectional area of liquid in pipe

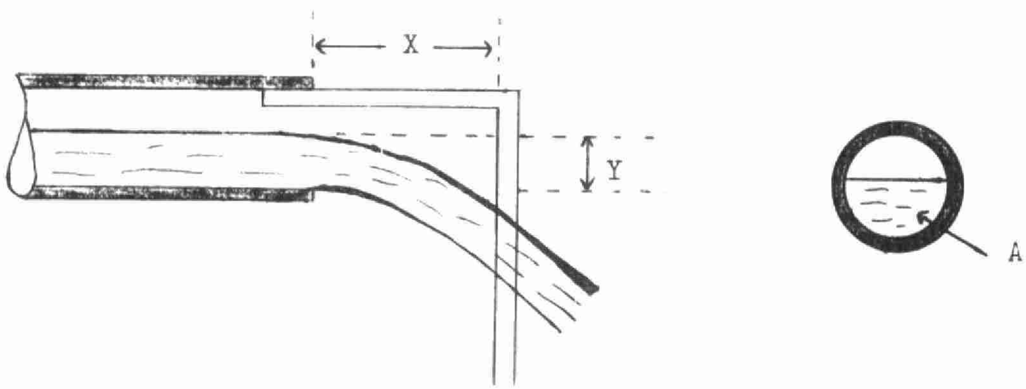
X = the distance between the end of the pipe and the vertical axis measured in feet (measurement is made parallel to the pipe).

Y = vertical distance in feet from the surface of the water at the discharge from the pipe to the intersection of the water surface with the vertical axis.

In practice, the actual flow pattern will rarely be as clean-cut as in Fig. 1 and some judgement will be required, particularly in the measurement of 'Y'.

FIGURE I

OPEN END PIPE DISCHARGE



It is important to note that this method of estimating the flow only applies where the pipe does not run full. A similar method can be developed for pipes running full but the formula is more complicated and outside the scope of this presentation.

(3) Velocity Measurement

The flow in certain pipes having relatively long straight runs may be approximated by estimating the velocity and using the formula:

$$Q = 9.64\ V \times A$$

where, Q = flow (Igpm)

V = velocity of liquid in pipe (ft./sec.).

A = cross-sectional area of pipe (sq. ft.).

The velocity may be estimated by timing the passage of a suitable indicator such as a piece of wood, a rubber ball, an orange, etc., through a measured length of the pipe.

(4) Standpipe Overflow Weir

This method of estimating the flow is also known as the California Pipe Method and is shown in Fig. II. The pipe must be perfectly horizontal so that depth of water in the pipe becomes a function of the flow through

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the pipe. The following formula can be developed to describe the relationship between flow and pipe:-

$$Q = 3250\ (1 - A/d)^{1.88} d^{2.48}$$

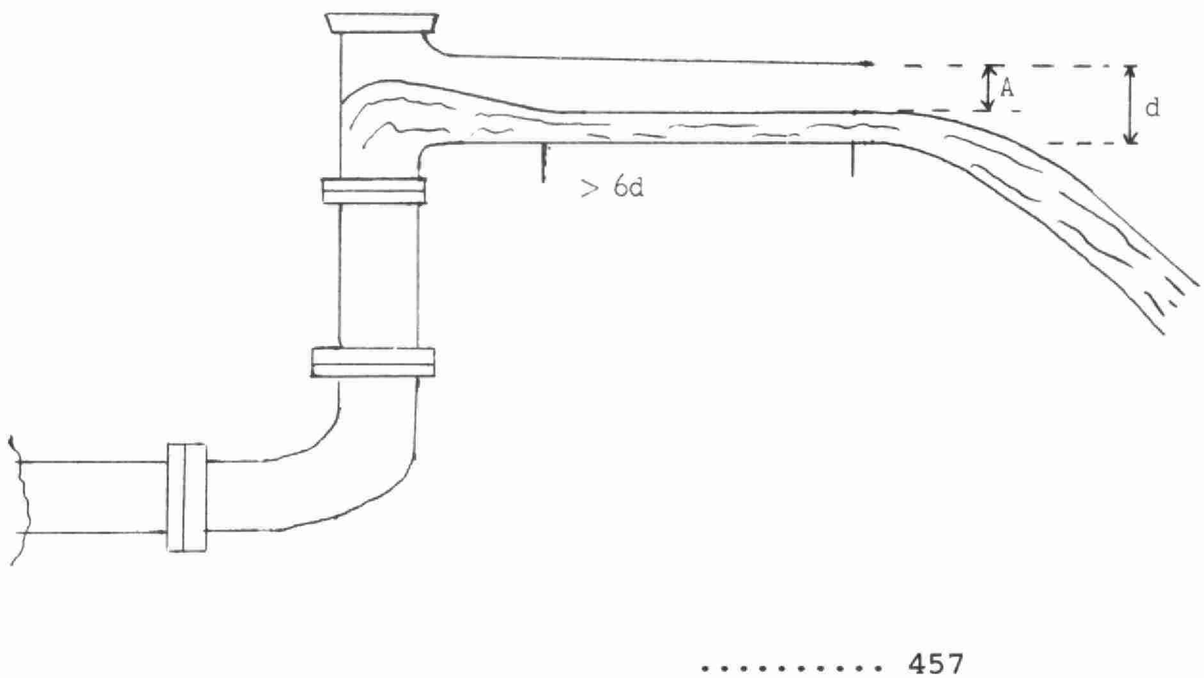
where: Q = volumetric discharge (Igpm).

d = pipe diameter in feet

A = vertical distance in feet between the upper inside surface of the pipe and the surface of the liquid.

FIGURE II

STANDPIPE OVERFLOW WEIR



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(5) Dilution Method of Flow Measurement

Where sewers are inaccessible or the installation of a flow measuring device is not feasible, the dilution method of flow measurement is recommended. This method employs the addition of a known concentration of material into the sewer at a constant rate followed by sampling of the mixture at a point downstream in the sewer where adequate mixing has occurred. A sample is collected also upstream from the point of addition to determine background levels and all samples are analysed for the diluted material.

Any material that is stable, non-reactive with the wastes in the sewer and that can be readily analysed may be used. Sodium chloride (common salt) is commonly used because sodium analyses are readily performed using flame photometry. Fluorescent dyes (fluorescein) may also be used as concentrations can be readily measured by the use of fluorometry.

The flow in the pipe may be computed as follows:

$$Q = \frac{q \times Co}{C_2 - C_1}$$

where: Q = flow rate in (Igpm)

Co = concentration of material added (mg/l or ppm).

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g = metered flow of material added (Igpm).

C_2 = concentration of material at downstream location (mg/l or ppm).

C_1 = concentration of material at upstream location (mg/l or ppm).

Example

Sodium chloride solution is fed to a sewer from a drum at the rate of 400 cc/min. (0.88 Igpm). The chloride content in the drum was sampled at various times and analysed as follows:-

t = 0	25,700 ppm
t = 1 hr.	24,000 "
t = 2 hr.	23,800 "
t = 3 hr.	23,500 "
Average	24,250 ppm

Samples taken at a point downstream showed the following chloride concentrations:

t = 0	38.70 ppm
t = 1 hr.	40.10 "
t = 2 hr.	36.20 "
t = 3 hr.	33.30 "
Average	37.10 "

The background chloride concentration upstream from the point of salt addition was 25.5 ppm. The average difference to chloride addition was (37.10 - 25.5) = 11.6 ppm.

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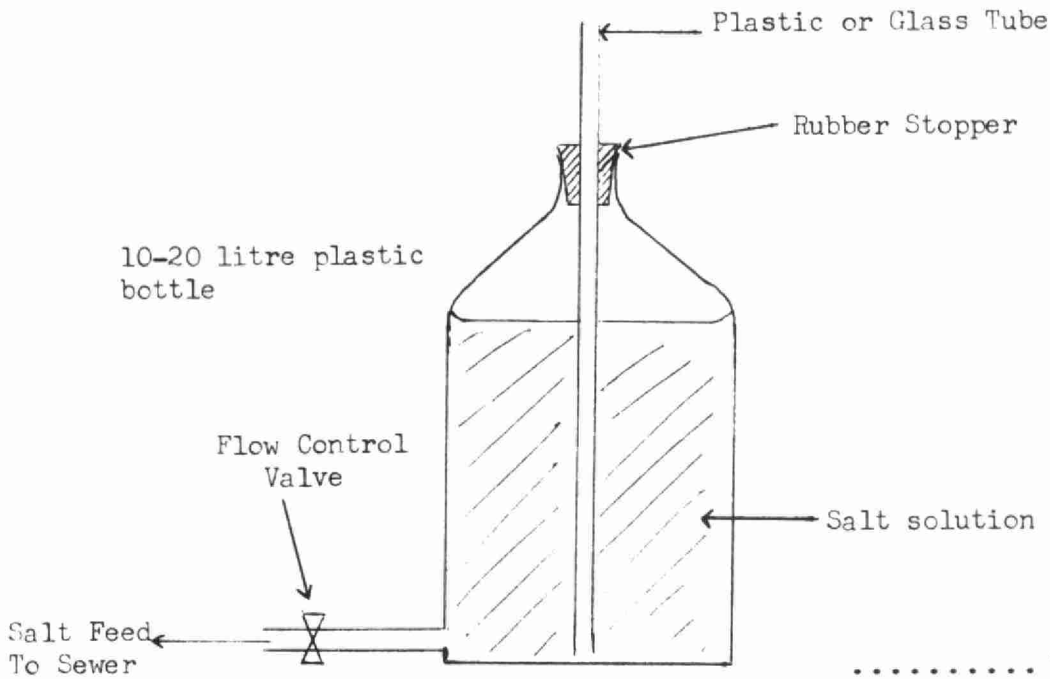
$$\text{Sewer flow } Q = \frac{24,250 \times (0.88)}{(37.10 - 25.5)}$$
$$= \frac{24,250 \times (0.88)}{(11.6)}$$
$$= 184 \text{ Igpm}$$

The most difficult part of this method is the maintenance of a constant feed rate of chloride solution. For a true constant feed rate, a constant head device is required either to feed by gravity or to provide a constant head for the suction of a small metering pump. The device shown in Fig. III has been used by the Ministry in the past with some success and is recommended as a convenient method of providing a near constant feed.

FIGURE III

CONSTANT FEED DEVICE



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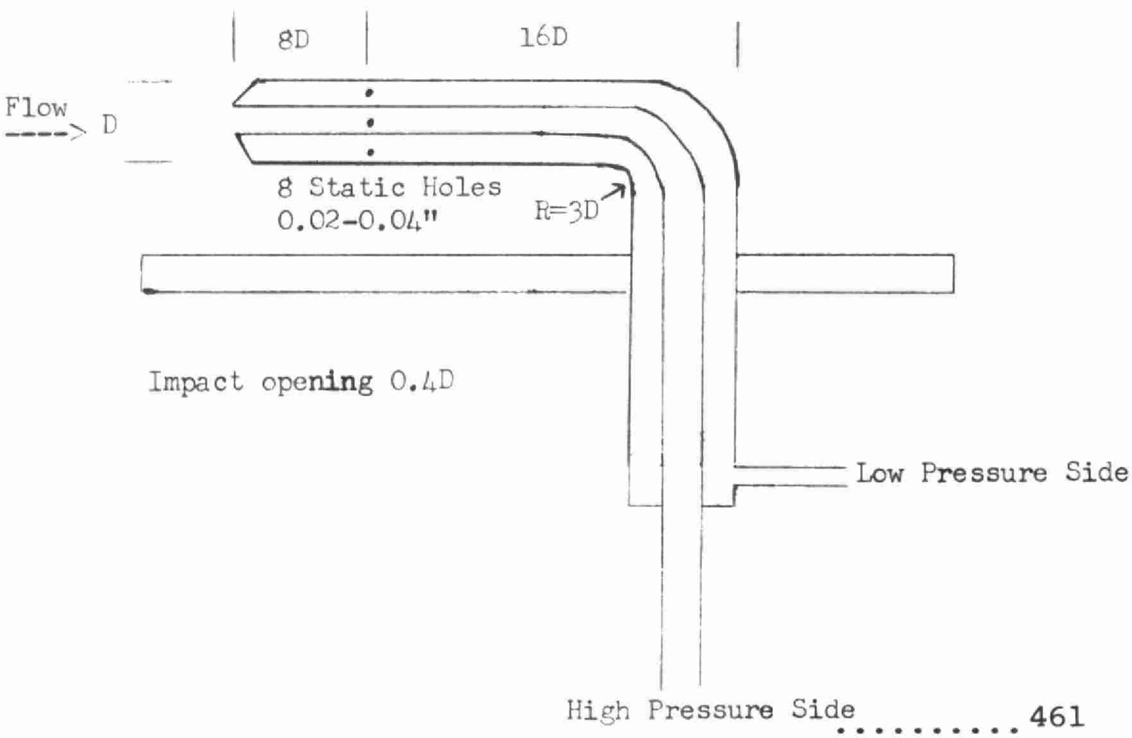
(6) <u>Velocity Measurement Using a Pitot Tube</u>

The pitot tube (Fig. IV) may be used for estimating the flow in a closed conduit or pipe, but its use necessitates the drilling of a small hole in the pipe to allow the tube to be inserted.

The most convenient type of pitot tube consists of a double concentric tube with the centre tube open at one end. At a distance of 8 diameters from the open end, a number of small holes are drilled through the outer tube. Other pertinent dimensions are shown in the figure.

FIGURE IV

PITOT STATIC TUBE



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In operation, the pitot tube is inserted into the closed pipe. The open end of the tube faces into the flow and the two other ends of the tube are connected to a manometer and the pressure difference is read.

As the velocity of flow varies across the section of a pipe, it is necessary to measure the velocity at a number of points across the pipe. Guidelines are available which designate the locations at which the velocity should be measured.

The mean velocity of flow in the pipe is then computed by averaging the velocities measured at each point on the traverse. If the cross-sectional area of the pipe is known, the flow may be computed from:-

$$Q = Va \times A \times 9.64$$

where Va is the mean velocity of flow

A = cross-sectional area of the pipe (sq.ft.)

Q = flow in Igpm

There are limitations on the applicability of the pitot tube, particularly at low liquid velocities and where suspended solids are present, and its use in liquid flow measurement is therefore limited. The interested reader is referred to a standard text on flow measurement for more details.

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(7) Flow Measurement by Head Loss

If a constriction is placed in a pipe or conduit carrying a liquid there will be an increase in velocity of the liquid as it flows by the constriction and a corresponding reduction in pressure (conservation of energy). The rate of flow through the constriction can be calculated if the pressure loss, the available area for flow through the constriction, the density of the fluid and the coefficient of discharge 'C', are known. 'C' is defined as the ratio of actual flow to theoretical flow and makes allowances for stream contraction and frictional effects.

$$Q = 9.64\, C \times A \times 2g \times \Delta h$$

where:
- g = acceleration due to gravity (ft./sec/sec)
- Δh = pressure loss in feet of fluid
- A = cross-sectional area at constriction (sq.ft.)
- Q = flow Igpm

If any difference in elevation occurs because of inclination of the pipe, a modified formula is required.

A number of devices have been developed which operate on this principle:

(a) Orifice Meter:
The orifice plate consists of a sharp-edged orifice

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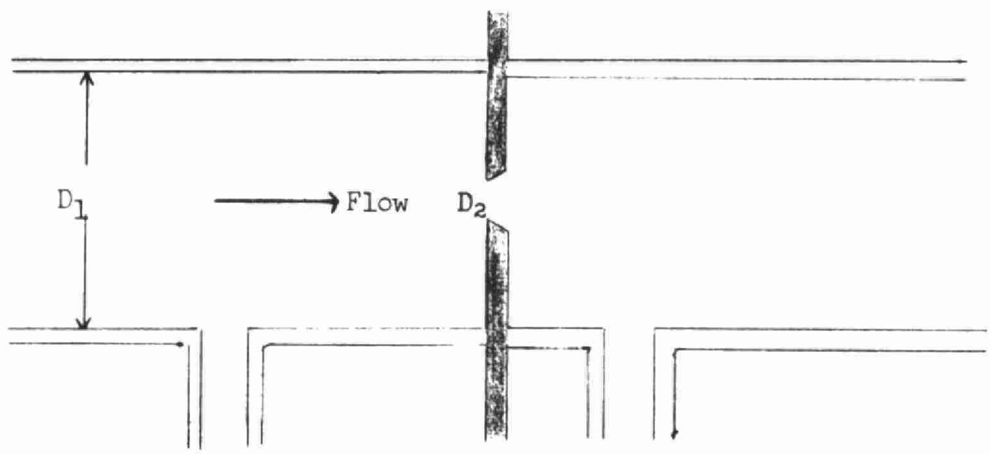
placed in the pipe to form the restriction. Pressure tappings are made upstream and downstream of the orifice with the distance of the tapping from the orifice being dependant on the type of tapping. Figure V shows the 'radius tapping' where the upstream hole is located 1 pipe diameter from the orifice and the downstream hole 1/2 pipe diameter from the orifice.

FIGURE V
ORIFICE PLATE

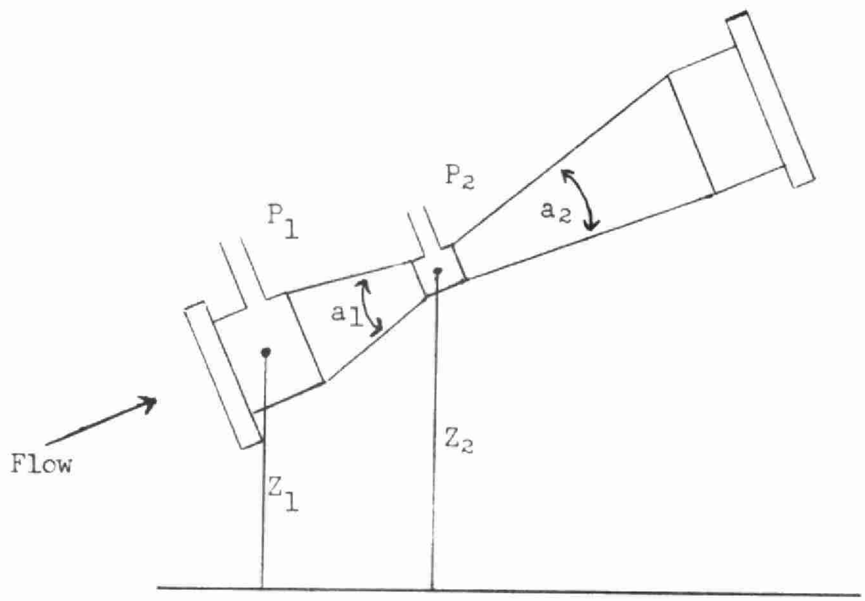


(b) Venturi Tube Meter

Greater accuracy can be obtained if the approach to the constriction and the discharge from the constriction are made more gradual. This is the principle of the Venturi - tube meter.

FIGURE VI

VENTURI TUBE METER



The angles for the cones of approach and discharge are specified at 21 $\pm$ 2 degrees and 5 - 15 degrees respectively, and the throat length is equal to one throat diameter.

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If the meter is installed in the horizontal position, the equation given for the orifice meter may be used. If the meter is inclined, a correction term must be included.

(c) Miscellaneous Head-Loss Meters

A number of variations on the orifice and venturi are available and all contain refinements that are claimed to give greater accuracy, greater life, self-cleaning features, etc. Orifices may be segmented or eccentric, particularly for applications where solids might build up behind a concentric orifice and affect the flow pattern.

A 90° elbow may be used as a flow measuring device if the differential centrifugal head between the inner and outer radii of the bend is measured by means of taps located midway around the bend. However, this measuring device requires calibration as determination of the discharge coefficient ("C") is not practical.

Square edged orifices and venturi tubes have been so extensively studied and standardized that reproducibilities within 1 to 2 percent can be expected when the meter is new and clean. Therefore, with accurate

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pressure measurement and correct selection of the discharge coefficient 'C' from the literature, this order of accuracy can be expected.

Care must be taken to prevent fouling and corrosion - a point often overlooked in many industrial installations.

(8) The Rotameter

This instrument has become very popular in the chemical process industry. It consists essentially of a plummet or 'float' which is free to move up or down in a vertical, slightly tapered tube having its small end down. The liquid enters the lower end of the tube and causes the float to rise until the annular area between the float and the tube wall is such that the pressure drop across this constriction is equivalent to the weight of the float.

The tapered tube is usually made of glass and has a linear scale etched on it. Interchangeable, precision-bore glass tubes and metal tubes are available. Also, floats of different densities are available for use with different liquids.

The manufacturer will usually supply a calibration curve for the instrument for the various tubes and floats.

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(9) Magnetic Flowmeter

To understand the principle of the magnetic flowmeter, it is necessary to review Faraday's law of electromagnetic induction. This law states that if a magnetic field is generated in one direction and a conductor is moved through this field at right angles to it, a voltage will be generated which is proportional to the speed of the conductor and the strength of the field.

Referring to Fig. VII, if an electromagnet generates a magnetic field of constant strength at right angles through a non-magnetic flow tube, and a conductive liquid (water) is passed through the tube, a voltage will be generated which is proportional to the rate of flow of the liquid. Two electrodes placed diametrically opposite each other in contact with the liquid, but insulated from the tube, are connected to an instrument to read the voltage generated. The flow tube is generally lined with an insulating material to prevent shorting of the voltage. An alternating current millovoltmeter of special design can be calibrated to read directly in units of flow.

For all practical purposes, any liquid having a

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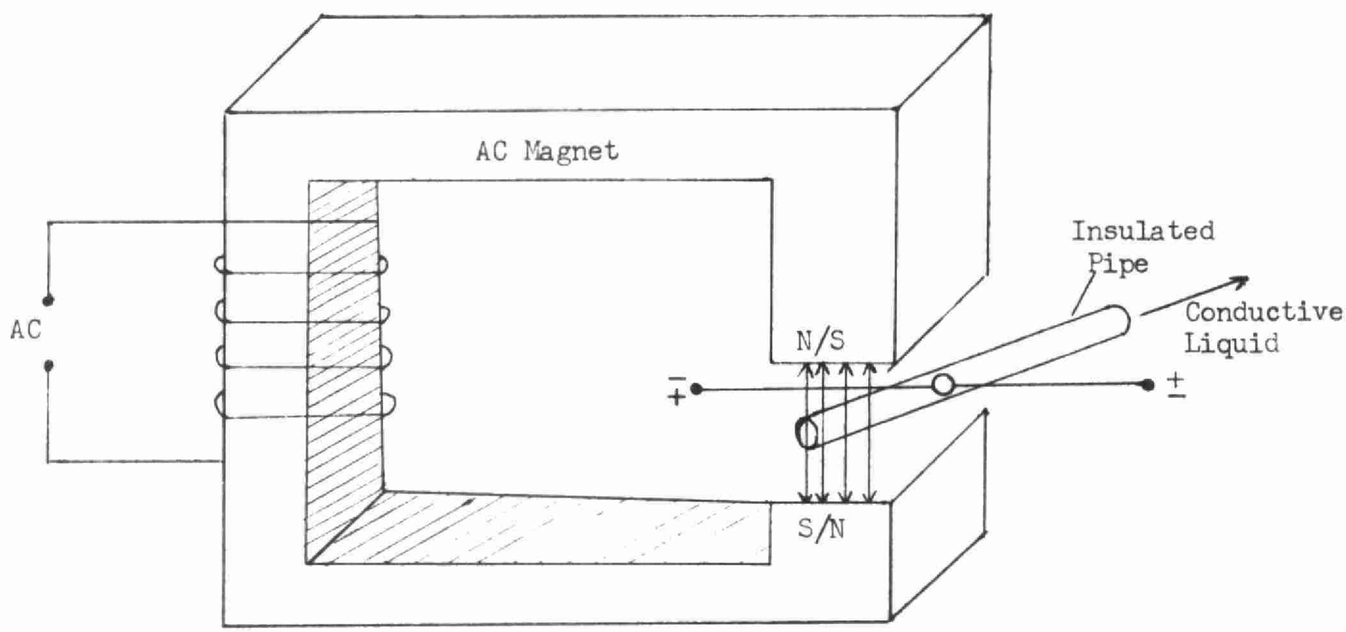
conductivity greater than 50 micromhos can be used in this type of meter. Most industrial wastes have conductivities greater than 100 micromhos and the meter is ideally suited for use with them.

FIGURE VII

MAGNETIC FLOWMETER



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(10) Turbine Meters

In this type of flowmeter, a turbine wheel or helical rotor is mounted on bearings concentrically in a pipe and parallel to the direction of liquid flow. The passage of liquid through the pipe causes the wheel to rotate, with the speed of rotation being a function of the flow. The rotating wheel is coupled either mechanically or electrically to a suitable metering device.

This type of meter requires calibration although this is usually done by the manufacturer.

(B) FLOW MEASUREMENT IN OPEN CHANNELS

In a plant a variety of open channel-type drains and sewers of varying cross-sections may be encountered, with the most common being the 'U' drain. For large industrial complexes it is also quite common for the total plant effluent to be discharged to the nearest watercourse by means of an earthen ditch. To measure the flow in channels of these types requires different techniques to those used for the closed pipe.

(1) Manning Formula for Open Channels

A liquid moving in a concrete drain or earthen

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ditch is subject to the hydraulic dimensions of the sewer. The specific parameters which govern the flow of water in an open channel are:

(a) the slope of the sewer (hydraulic gradient)

(b) the width of the channel

(c) the depth of the water in the channel

(d) the roughness coefficient of the channel bed

Manning, in 1890, published an expression relating the flow in an open channel to these parameters:

$$Q = \left(\frac{1.486}{n}\right) \times A \times R^{0.67} \times S^{0.5}$$

where:

Q = flow (cubic feet/sec.)

n = roughness coefficient

A = cross-sectional area (sq.ft.)

R = hydraulic radius = $\frac{\text{wetted perimeter}}{\text{Area}}$ (ft)

S = slope of water level (ft/ft)

Values for 'n' have been determined experimentally for various materials and are available in the literature. For a variety of materials, these values lie in the range 0.01 - 0.03.

For a uniform channel, the flow may be calculated by determining the depth, the channel slope and selecting

the appropriate roughness coefficient. The hydraulic slope, for all practical purposes is equal to the channel slope in cases where the flow is uniform and where obstructions causing backwaters are absent. However, flows in most industrial sewers are too small and non-uniform to be accurately estimated by use of the Manning formula and its application is therefore limited.

(2) <u>Weirs</u>

The weir is the most common device used to measure flows in small open channels. A weir is a constriction placed in the channel which provides a known length over which the flow must pass. A relationship can then be established between the liquid flow and the head developed by the constriction. A weir may also be a depression in the side of a tank, channel or ditch, or it may be an overflow dam. Weirs are generally classified according to the shape of the notch; e.g., rectangular, triangular, V notch, trapezoidal, parabolic, etc.

The edge or surface over which the water flows is called the crest and the overflowing sheet of water is called the 'nappe'. The depth of water producing the discharge, 'H' is called the head. A weir with a sharp upstream edge so formed that the water springs clear

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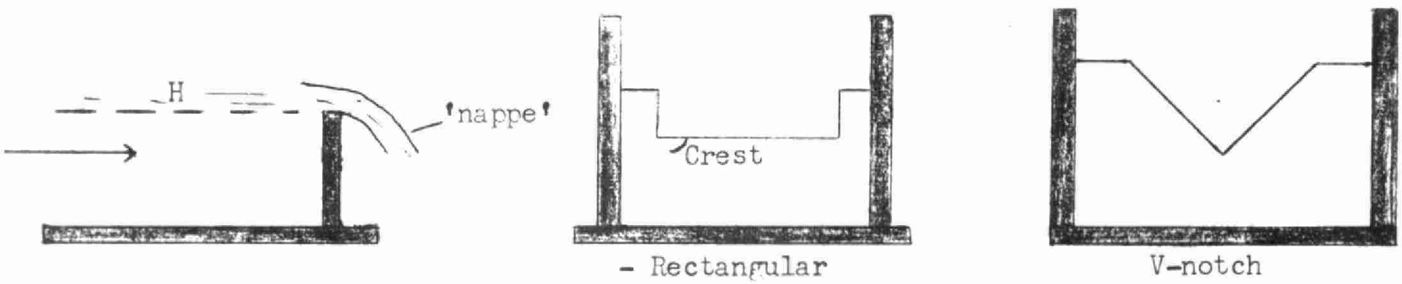
of the crest is called a sharp-crested weir. If the nappe discharges into the air as in Fig. VIII the weir is said to be free-discharging. If the discharge is partially under water as in Fig. IX the weir is said to be submerged.

FIGURE VIII

SHARP CRESTED FREE DISCHARGING WEIRS



(a) Sharp-Crested, Rectangular Free Discharing Weirs

The most widely used formula for the standard weir is the well known "Francis" formula:

$$Q = C \times L \times H^{1.5}$$

where:
- Q = flow (cubic feet per second)
- L = length of weir crest (ft.)
- H = head on weir (ft.)
- C = a coefficient

Tables are available in most texts to solve this formula for various weir lengths. There are numerous other formulae available for calculating sharp-crested,

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free discharging weir flows, each adding refinements to yield greater accuracy.

(b) Sharp-Crested 'V' - notch Weirs

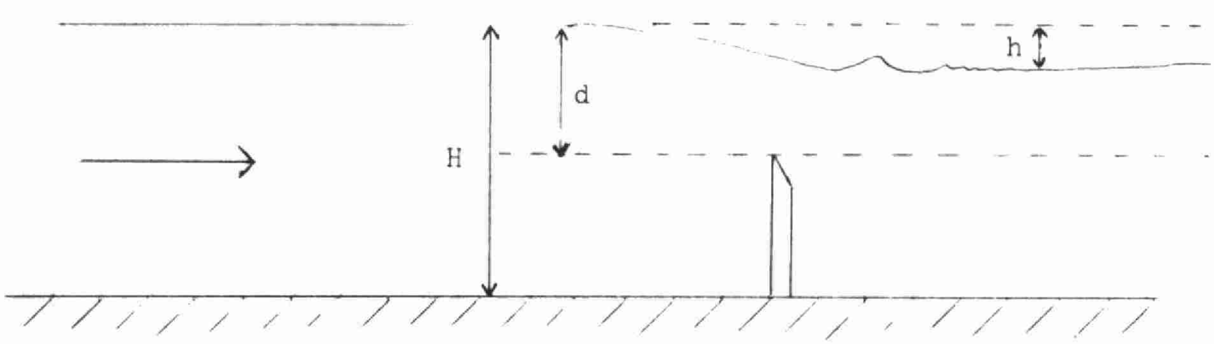
The triangular or V-notch weir is used for measuring small discharges where the rectangular weir becomes relatively insensitive to flow variation. 60, 90 and 120 - degree triangles are frequently used and the formulae for computing the flow are:

$$Q = 1.44\ H^{2.5} \quad - \ 60^{o}\ \text{weir}$$
$$Q = 2.5\ H^{2.5} \quad - \ 90^{o}\ \text{weir}$$
$$Q = 4.33\ H^{2.5} \quad - \ 120^{o}\ \text{weir}$$

(c) Submerged Sharp-Crested Weirs

FIGURE IX

SUBMERGED WEIR



This type of weir is desirable when sufficient head is unavailable for selection of a more accurate weir or other measuring device. The discharge over such a weir is related to the upstream head, the downstream head and the depth of submergence of the weir. The Francis formula approximates the flow when the weir is sharp-crested:-

$$Q = C \times L \times \sqrt{h} \times (H + 0.38d)$$

where:
- Q = flow (cfs)
- L = weir length (ft.)
- H = upstream weir head (ft.)
- h = elevation drop ($H_1 - H_2$)
- d = depth of submergence (ft.)
- C = weir coefficient - generally = 3.33

(d) <u>Broad-Crested Weirs</u>

A weir is considered broad-crested when the head over the weir is less than twice the breadth of the weir. These weirs do not provide the accuracy of flow measurement of a sharp-crested weir due to the inconsistency in establishing coefficients for all the types of broad crests. Characteristics such as rounding the ends of the broad crest, roughness coefficients of materials used and the shape of the water level over the

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crest are some of the factors that have to be considered in the evaluation of the coefficient. An approximation of the flow over most broad crested weirs can be obtained by using the following formula:-

$$Q = C \times L \times H^{1.5}$$

where:

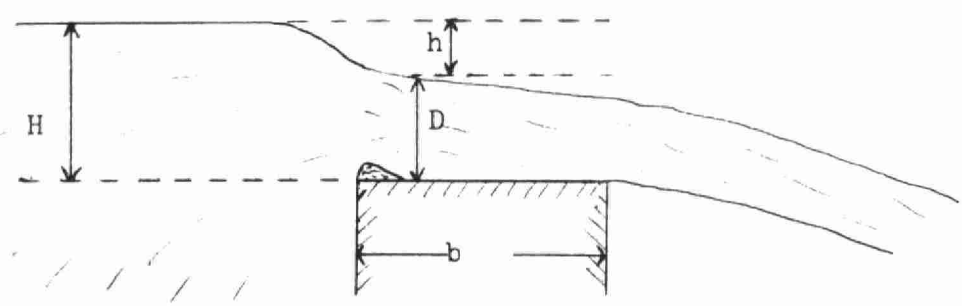
L = weir length (ft.)

H = head on weir - measured at least 2.5 H upstream from weir.

C = weir coefficient - equal to 2.63 where the weir head is greater than 1.5 feet.

FIGURE X

BROAD-CRESTED WEIR



(e) <u>Cippolletti Weir</u>

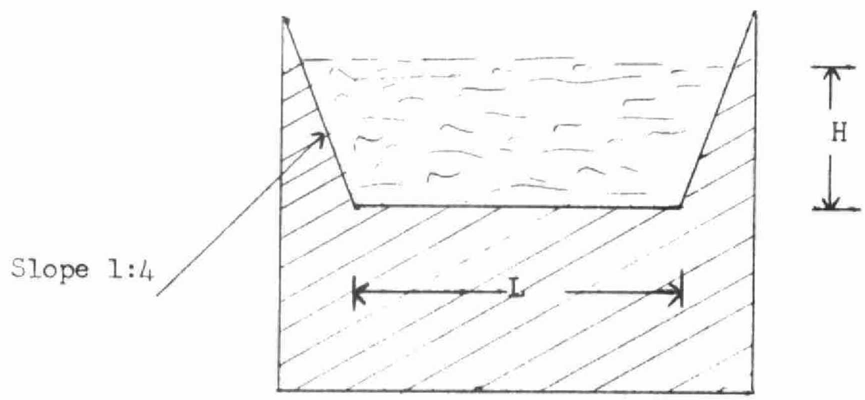
This weir has a trapezoidal cross-section with side slopes of 1:4 (horizontal to vertical). The slope provides sufficient additional passage area to compensate for contractions at the ends and adjustments for these contractions do not have to be made. The following

formula can be used to approximate the flow through such a weir:-

$$Q = 3.3 \times (C \times 2/3\ L) \times H^{1.5}$$

FIGURE XI

CIPPOLLETTI WEIR



(f) Circular Weir

Stand pipes used to control tank level can be used to measure flow as they represent a circular weir. Circular weirs have no end contractions and provided vortex action is not established in the stand pipes the flow may be estimated by:-

$$Q = 0.0243\ d \times h^{1.4}$$

Q = flow (cfs)

d = pipe diameter (inches)

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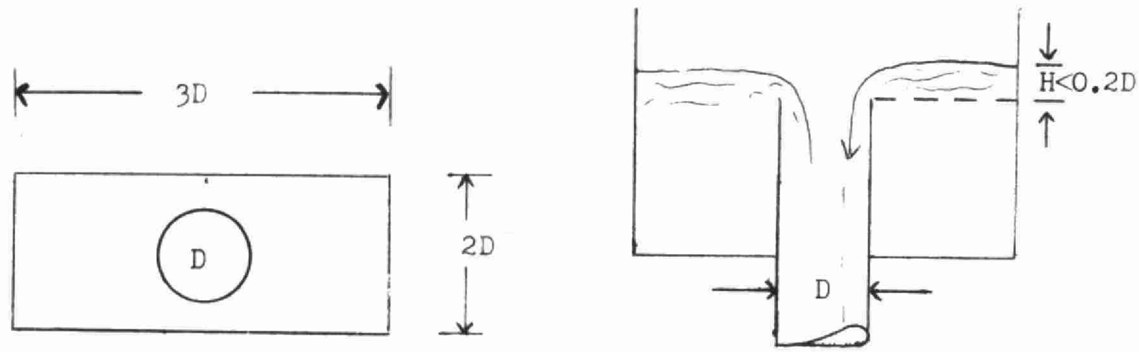
h = head on weir 3-5 diameters back from overflow (inches)

Some of the limiting dimensions are shown in Fig XII.

FIGURE XII

CIRCULAR WEIR



(3) <u>Velocity Measurement</u>

If the average velocity of the flow in an open channel is known and the cross-sectional area can be calculated, then the flow can be calculated from the formula:

$$Q = V \times A$$

where: Q = flow (cfs)

V = velocity (ft./sec)

A = area (sq.ft.)

A number of methods are available to measure the velocity.

(a) <u>Stop Watch Method</u>

In this method, the velocity of the surface waters is calculated by measuring the time of travel of a floating object over a measured distance. Wood chips, oranges, rubber balls, partially filled bottles, etc., may be used with success. For most channels, the surface velocity is about 15 percent greater than the average channel velocity and the maximum velocity occurs at about 0.4 of the distance from the surface to the channel bottom.

This method gives a quick assessment of the flow.

(b) <u>Current Meters</u>

A number of companies manufacture devices which may be used to measure the velocity of flow in a channel or body of water. The two most commonly encountered are the Ott Meter and the Gurley Meter.

The Ott meter consists of a free-rotating helical propeller mounted on a suitable support to allow it to be lowered into the water. The Gurley meter is similar except that the propeller is replaced by a set of rotating cups, similar to those of a wind velocity meter. In operation, the rotating portion is lowered into the water and the revolutions per unit time are

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counted by some suitable means such as the transmission of an impulse signal. The revolutions are proportional to the velocity of flow and the actual velocity can be read from a calibration chart relating revolutions per unit time to flow. A number of velocity readings should be taken at various distances across the channel and at varying depths and then averaged to yield the average stream velocity.

These instruments are portable and are very useful in checking flows where no built-in device is available.

(4) <u>The Parshall Flume</u>

Fig. XIII shows the typical design and dimensions of the Parshall Flume. Because the flume has a contraction at the throat, the velocity of the liquid flowing through the flume is raised and any sand or silt will be prevented from settling. Thus the flume is to some extent self-cleaning although deposits (slime growth, etc.) can occur on the sides which will affect the accuracy.

This type of flume is more expensive to build than a weir and requires more accurate construction techniques.

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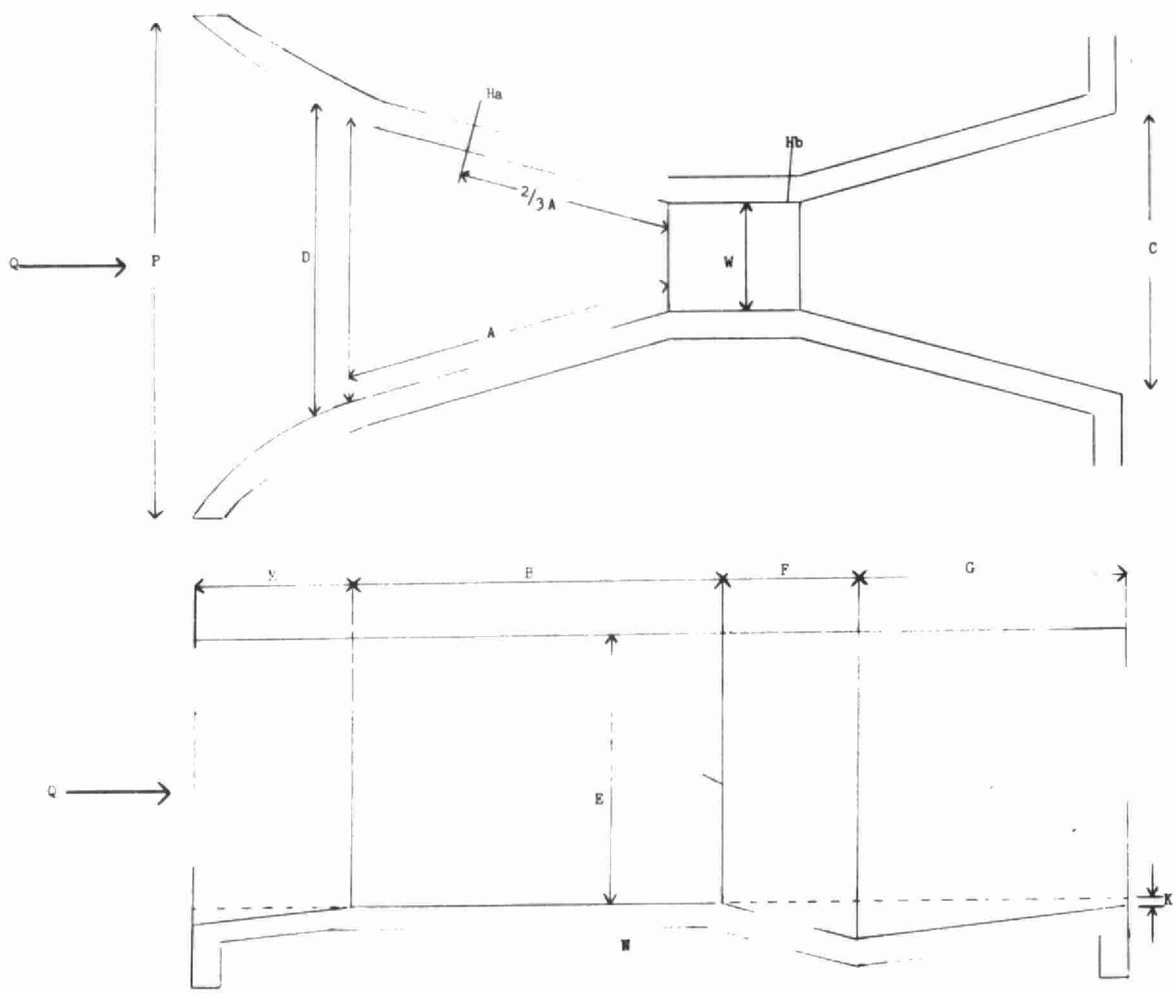
FIGURE XIII



The flume consists of an open-channel venturi section, a converging inlet section, a downward sloping throat, and an upward sloping, diverging outlet section. Materials of construction can be concrete, plastic, metal or wood.

Specific design criteria must be adhered to when building Parshall flumes to ensure that the flume operates correctly. Also, for the same reason, selection of the correct size flume is critical. Table A shows some typical dimensions for a six-inch flume. Of interest is the location of the upstream gauge station, Ha. The head of water in the flume is measured at Ha which is $\frac{2}{3}$ the distance of the converging wall, A, from the commencement of the throat.

Further details on flumes and their application can be obtained from any standard text on fluid mechanics, but Table B gives the formulae for calculating the flow through various weir sizes.

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TABLE A

Typical Dimensions (refer to Figure XIII)

For W = 6"

A	=	24 7/16"	G	=	18"
B	=	24"	K	=	3"
C	=	12½"	N	=	4½"
D	=	15 5/8"	N	=	12"
E	=	24"	P	=	35½"
F	=	12"	Cubic Feet Per Second	=	0.05 - 3.9

TABLE B

Approximate Equations

Width	Formula	
3"	$Q = 0.992\ Ha^{1.54}$	Q - cfs
6"	$Q = 2.06\ Ha^{1.58}$	W - ft.
9"	$Q = 3.07\ Ha^{1.53}$	Ha - ft. liquid
12 - 24"	$Q = 4W\ Ha^{1.52}$	

CONCLUSIONS

A variety of methods are available for estimating the flow in both open channels and closed conduits or pipes. Some of the more common of these methods have been presented for your consideration but there are many more that have not been mentioned.

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TRACING INDUSTRIAL

WASTE SPILLS

TO THE SEWER SYSTEM

INTRODUCTION

As an industrial waste officer, you may be notified that there has been a spill of some foreign material to either the storm or sanitary sewers. Most spills occur when a material is accidently or deliberately dumped to the sewer system while others occur due to equipment failures. When a spill is directed to the sanitary sewer, the sewer maintenance crews, or the Sewage Treatment Plant operators, are the first to complain. In a storm sewer system, a spill is usually detected in the watercourse downstream of the storm sewer outlet. Spills to a storm sewer system are normally reported by local residents although recent legislation by the Province of Ontario, which makes it an offence for failing to report a spill, has prompted the responsible party to report the loss.

In this paper, a brief examination of the techniques of tracing spills in sewer systems will be undertaken and some of the spill incidents we have had in the Town of Mississauga will be discussed. Since the Town of Mississauga started its Industrial Waste Program on a full time basis, there have been approximately twelve reported spills to the storm sewer system and four to the sanitary sewer system.

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Of the twelve spills to the storm system, all but one were traced to the source and in the sanitary system three were traced.

TECHNIQUES OF TRACING SPILLS

The most important considerations in successfully tracing spills are your familiarity with or knowledge of the sewer system and the industries which are serviced by it. You should arrange, if you haven't already done so, to acquire an up-to-date set of drawings depicting both the location and direction of flow for both the sanitary and the storm sewer system. The best way to glean the required information is to conduct a door-to-door industrial waste survey of each industry on the system. In the Town of Mississauga, a survey of all the industries has been completed and basic information has been recorded on a master list as illustrated on the following page.

TOWN OF MISSISSAUGA INDUSTRIAL WASTE DATA SHEETS

STREET - CRUDSVILLE AVE.

Company and Street No.	Class	Status	Field Visits	Annual Visits Req'd.	MATERIALS
Franks Galvanizing Co. Ltd. 1302	903	1 1S	Dec. 1/71 Apr. 14/72	4	H_2SO_4, NaOH HCl, Molten Zinc, Pb^{++}, Zn
Quality Plating Co. 1529	092	1S	Nov. 15/71 Apr. 14/72	4	Chemicals Contain Zn, Cu, Cr, H_2SO_4 NaOH
Burley Foods Ltd., 1986	027	2S	Apr. 1/72	2	NaOH, orange and lemon peel

You can see from this example that the potential source of a spill could be narrowed somewhat by analyzing your sewer drawings to predict the possible street source. Then, by examining the street data sheets, the characteristics of the material involved in the spill can be matched with the chemicals listed in the last column of the "Industrial Waste Data Sheets".

Another important facet involved in tracing a spill is identifying the foreign substance involved. A sufficient volume of sample should be obtained and submitted to a reliable laboratory for identification of the contaminants present. Upon sampling, other significant details should be observed and duly recorded. The colour, odour, texture, or any other physical characteristics may provide the necessary clues for quick tracing. For example:

(1) a reddish-brown coloured waste which may be acid is probably a spent pickling acid.

(2) a green or yellowish-green coloured waste might be chromic acid or sodium dichromate, and

(3) the scent and texture created by impurities in waste oil or solvent may provide enough clues

to suggest the industry responsible for the spill.

There are many examples of chemicals and materials which may provide enough information to predict the type of industry responsible for the spill. The papers presented in Section (b) of this course, entitled "Specific Industries - Problems and Solutions", will deal more specifically with this particular aspect of identifying waste materials.

CASE #1

On July 2, 1970, a complaint was received concerning the reddish-brown discolouration of the water in Mimico Creek at Malton. The colour was first noticed on July 1, 1970 and it was estimated later that the chemical had been dumped to the storm sewer system late on Tuesday June 30, 1970, just before the plant stopped production for the Dominion Day Holiday. The next two days were spent tracing the reddish-brown colour for approximately 2 miles in Mimico Creek and in an open municipal storm drainage ditch. In the upper limits of the ditch, the intense discolouration of the water had been diluted by heavy rain on July 2. The head walls for the storm sewer outlets to the drainage ditch were closely inspected, and it was found that the Bren Road storm sewer had faint reddish-brown stains on

the wall of the sewer. Samples of water were obtained above and below this outfall; however, the results were not conclusive. At this point, it was decided to inspect the Bren Road storm sewer. From the master list it was found that only three companies had chemicals and that only one of these had pickling acids available. The sewer was then inspected closely and it was found that the reddish brown stains were more intense below than above the lateral servicing the suspect company which galvanizes steel. Upon interviewing management, it was of course stated that it was impossible that the waste had come from the plant because all spent chemicals are taken away by an industrial waste haulage contractor. We insisted on discussing the matter with this contractor, but the Plant Manager could not remember the name of the haulage company nor could he find the accounting documents to support his claim. It was, therefore, decided to try to obtain the necessary evidence and summons the company under the terms of the (then) O.W.R.C. Act.

The storm sewer on Bren Road is 42" in diameter which permitted entry to the system for close examination. At the junction of the lateral and the storm sewer, very intense reddish-brown splash marks

were visible on the wall of the sewer opposite the lateral. Pictures were obtained to illustrate the chemical splash markings at the lateral of the suspect company. Samples of the water and the sediments (actual sewer scrapings) were obtained and taken to the Ministry Laboratory for analysis. The samples were:

1. Sample of sewer scrapings above the lateral of the company - August 24/70.
2. Sample of sewer scrapings in the company's storm sewer lateral - August 24/70.
3. Sample of sewer scrapings below the lateral of the company - August 24/70.
4. Sample of water taken from the company's sump in galvanizing area - August 24/70

Other samples taken earlier were:

5. Sample of water in Mimico Creek above the spill area - July 2, 1970.
6. Sample of reddish brown water in Mimico Creek - July 2/70

<u>Results of analysis of samples</u>

	Fe	Zinc
1	2,500	19
2	12,100	6300
3	11,800	6000
4	6,800	3150

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	Fe	Zinc
5	0.8	0.04
6	7.8	2.4

Results in parts per million (ppm)

It may be seen from the analytical results that iron and zinc concentrations in the sewer scrapings increased by a factor of 5½ and 300 respectively below the company's lateral. The regular portland cement used in the manufacture of concrete sewers contains approximately 10 percent calcium aluminate. When a high sulphate waste such as sulphuric acid is dumped to the sewers, it reacts with the lime in cement to form calcium sulphate. Calcium sulphate then reacts with the calcium aluminate ($4CaO.Al_2O_3.19H_2O$) to form a calcium-sulphate-aluminate molecule as $3CaO.Al_2O_3.3CaSO_4.31H_2O$. The reaction causes the concrete to swell and crumble and this physical-chemical change could trap some of the waste constituents. Essentially, the sulphuric acid containing high concentrations of zinc passing over a concrete sewer would be neutralized by the free lime, and the resultant physical change in the sewer could trap the zinc which would be converted from zinc sulphate to zinc hydroxide by the free lime.

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CASE #2

On February 17, 1971, a complaint was received that there was considerable accumulation of oil and oily-sludge at a storm sewer outlet channel. A considerable quantity of oil had accumulated behind the gate at the storm sewer outlet, and along the ditch to its confluence with Little Etobicoke Creek. Theoil at the creek disappeared under the ice cover, and it was estimated that approximately 1000 gallons of immiscible machine oil remained. There was also an accumulation of several cubic feet of an oily-sandy like sludge.

Upon investigation it was established that the sandy sludge was actually sodium chloride or salt sludge containing machine oil and metal fines. The oil did not adhere to the wall of the 60 inch storm sewer and this made it difficult to establish the source. Arrangements were made with the Works Department to assist in walking through the sewer. It was found that some of the oily-salt sludge had settled in the small openings at the joints of the sewer. This condition was traced to the suspect industry where samples were obtained as follows:

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1 - Sediments in storm sewer below the suspect company.

2 - Sediments in the company's settling tank.

3 - Sediments in ditch at outlet to Etobicoke creek.

	Fe	Cr	Cl
1	250	240	2300
2	420	306	80000
3	15	1.2	1300

The oil present in the ditch was sampled and submitted to the Ministry's Laboratory. Two days later the survey of the entire industrial development with some 75-80 industries on this storm sewer system was completed and it was found that there were ten industries with the same type of oil. On close inspection of the storm sewer facilities servicing these industries, it was established that two industries had significant amounts of the same oil found in the catch basins and in the effluent from the sewer laterals. Samples of the oil in each case indicated that the oil was similar in nature to the oil found at Etobicoke Creek. When these companies were informed of the significance of these findings, they took steps to eliminate the possibility of oil gaining access to the storm system. One company installed a pad to serve as a convenient

spot to dump waste oil and store oil covered scrap metal. The drain from this pad was then connected to an underground holding tank. The pad was curbed to prevent storm water entering the system, and company staff indicated that after one year's operation approximately 1000 gallons of storm water and 2000 gallons of waste oily-water emulsion have been taken away. The other company had problems with employees indiscriminately dumping waste oil sludges to the storm-water catch basins even though holding tanks were provided for these wastes. The management found that to curb this action by employees they had to weld a steel plate over the catch basin and employees caught dumping wastes were laid off for two weeks. This procedure had the necessary emphasis because in the last year no oil or salt sludge has been detected in the storm sewer.

SUMMARY

The old adage "You can't put a price on good experience", certainly applies to industrial waste inspectors because it is very important to trace all spills to their source thereby possibly eliminating a recurrence. As mentioned before, your knowledge of the industries and the sewer systems servicing your industrial areas is very important. Prompt and direct action may enable you to establish

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the source of a spill before the trail is cold. Spills may involve purely accidental losses of materials but it often happens that plant staff unwittingly or deliberately discharge wastes to the sewer system. Success in tracing a spill will reduce complaint calls, unnecessary corrosion and additional maintenance of the sewers and sewage treatment facilities. Most important, it may reduce pollution directly or indirectly and expertise in spill tracing therefore should be actively pursued.

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THE ROLE OF THE ONTARIO MINISTRY
OF THE ENVIRONMENT
IN INDUSTRIAL WATER POLLUTION CONTROL
IN MUNICIPALITIES

The Ministry of the Environment is responsible for ensuring that adequate means of controlling water pollution are carried out by industries, municipalities and private persons in Ontario. This responsibility is given by legislation embodied in the Environmental Protection Act and The Ontario Water Resources Act which are currently undergoing revision and integration into one over-all comprehensive legal document.

There are several areas of the Ministry which are involved in water pollution control in municipalities, such as the Sanitary Engineering, Industrial Wastes and Private Waste and Water Supply Branches. However, for the purposes of this presentation, control of wastes from industries in municipalities and the role of the Industrial Wastes Branch will be the main topic of discussion.

As you are all aware, this course is being conducted under the auspices of the Industrial Wastes Branch. The Industrial Wastes Branch is responsible for the administration of the Province's industrial water pollution control programmes. The Branch investigates and reports on industrial water-use and waste disposal, and recommends measures for the

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treatment or control of waste discharges that do not conform with the Ministry's water quality and industrial effluent objectives.

The activities of the Branch fall into three general areas: Field Services, Design Approvals, and Special Projects.

The Field Services Section carries out the following functions:

(1) Investigating all industries in the Province having significant industrial waste discharges to natural watercourses:

(a) to determine the sources, magnitude and character of these wastes;

(b) to prepare engineering reports on these investigations;

(c) to negotiate with industry for the implementation of satisfactory pollution control programmes; and,

(d) to evaluate the performance of existing treatment works.

(2) Providing advice and assistance to industries in making application to the Ministry for approval of industrial waste treatment works.

(3) Maintaining a quality and quantity inventory of industrial waste discharges to watercourses in Ontario.

(4) In co-operation with other Branches such as Project Development, Sanitary Engineering and Project Operations, offering advice and technical assistance to municipalities and industries in the regulation and treatment of industrial wastes in new or existing municipal sewage treatment facilities to ensure compliance with sewer-use by-laws.

(5) Providing industrial waste data for use by the International Joint Commission, the Federal Government and other Provincial Government agencies relating to programmes for the protection of international and provincial boundary water quality.

(6) Giving technical assistance to the Legal Services Branch in the prosecution of industries under the terms of the Ontario Water Resources Act.

(7) Providing advice to deal with accidental spills, leaks or other emergency industrial pollution situations.

The Special Projects Section carries out the following functions:

(1) In co-operation with the Project Development Branch and the Design Approvals Section of the Sanitary

Engineering Branch, reviews conceptual and final design reports for provincially financed municipal sewerage schemes with respect to potential and existing industrial waste loadings and the measures necessary to ensure acceptable treatment performance at the Sewage Treatment Plant.

(2) In co-operation with the Research and Laboratories Branches, provides specialized technical appraisal of difficult industrial waste treatment problems on an individual or industry-group basis.

(3) In co-operation with the Project Development and Legal Services Branches, offers advice to municipalities in the preparation of sewer-use by-laws for regulating industrial discharges to municipal sewers.

The Design Approvals Section carries out the following functions:

(1) Reviews all applications from industry for the approval of plans for the collection, transmission, treatment and disposal of industrial wastes, where the effluent from such facilities are to be discharged to a natural watercourse or storm sewer. Certificates of Approval for such facilities are subsequently issued.

(2) Arranges public hearings concerning these applications.

(3) In co-operation with the Information Services Branch, prepares news releases on proposed industrial

waste treatment systems which may be of interest to the general public.

The onus for preventing pollution or impairment of water quality, which may result from the discharge of municipal effluents to watercourses, rests with the municipalities and they are being encouraged to accept this responsibility. Sewer-use by-laws should be enforced and any special agreements with industry properly administered. Some municipalities retain consulting help while others have set up their own enforcement and control agencies. In any case, this Branch is always available for consultation should the need arise.

The Branch is prepared to advise on a number of matters which include:

- technical and legal procedures for enforcing provisions of the municipal by-law;
- design of pretreatment plants for industries to ensure that problems are not created in the municipal sewerage works; and
- the location of new industries in a municipality and the potential effects of the anticipated wastes on the municipal sewerage works.

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Where a municipality is contemplating the construction, modification or expansion of its treatment facilities, it is necessary to define the nature of the industrial effluents being discharged to the sewers and also determine the actual waste loadings. The Industrial Wastes Branch can undertake what is termed a municipal-industrial wastes survey. All industrial and commercial firms are considered and sampling and analysis is carried out on all significant industrial discharges both to the sewage system and watercourses in the municipality.

In the interest of maintaining control of the quality of sewage being delivered to a sewage treatment plant which is required by the Ministry or otherwise dictated, by-law enforcement is mandatory. Treatment plant malfunctions and damage have occurred at many locations because municipalities do not have industrial by-laws or have failed to enforce them where by-laws do exist. Municipal officials must know the industries in their municipalities, the nature of the industrial operations, products, etc., as well as their wastes. They may be asked to make suggestions regarding pretreatment of wastes. They should, therefore, have some knowledge of both industrial waste and sanitary sewage treatment.

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The texts used for the instruction of Sewage Plant Operators at our Ministry courses as well as a set of the Proceedings of the Annual Industrial Wastes Conference would be invaluable for reference purposes.

Most municipal industrial wastes by-laws include reference to storm sewers, drains and ditches. Certain prohibitions are set out because these appurtenances often are used to discharge untreated wastes directly to watercourses and for all practical purposes the waste quality requirements are identical with those for direct discharge to a watercourse. As mentioned before, direct discharges to watercourses are the responsibility of the Ministry and, therefore, storm water discharges are included under this jurisdiction. However, the municipality also wishes to protect its sewers, pumping stations, etc., from corrosion and physical damage and, therefore, a section on storm sewers is usually included in the ordinance.

In the event of the discharge of unacceptable wastes by an industrial or commercial plant to a municipal storm sewer, two courses are open to the municipality. First, if a nuisance condition exists, a ready remedy can be obtained by enforcing the by-law. Alternately,

if serious impairment of water quality in the receiving watercourse is encountered, the Industrial Wastes Branch should be informed for appropriate action to be taken under the Ontario Water Resources Act.

This Branch collaborates with the Project Operations and Sanitary Engineering Branches in consulting with local Advisory Committees, Utilities, Commissions, etc. The Branch can be called in where sewage treatment plant malfunction is attributed to industrial wastes. Investigations will be conducted at the "suspected" industries to determine what is causing the upset. Hopefully, in the future much of this work will be undertaken by trained municipal employees with advice and assistance from this Branch.

The Ministry has the power to require municipalities or persons to discontinue or regulate the discharge of sewage which interferes with the proper operation of sewage works. Should a municipality fail to enforce its by-law, then the Ministry, through the Industrial Wastes Branch, can move in to carry out the necessary studies and prepare orders to effect correction of the problem. Such action is rare, but should reluctance, on the part of the municipality or industry to co-operate

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be encountered, this legal tool can be used.

The role of the Industrial Wastes Branch in municipal control of industrial wastes has been outlined and the belief that encouraging municipalities to accept their responsibilities can minimize the cost of administering the Province's pollution control programme has been stated. By applying their by-laws independently and fairly, municipalities can maintain not only local good will but also ensure that the treatment plant discharge meets the Ministry's objectives for discharge to the Province's waters.

REGULATION OF INDUSTRIAL WASTES
IN MUNICIPAL SEWERS -
SEWER-USE BY-LAWS

The following is a review of some of the legislation concerning municipal sewer-use by-laws.

THE MUNICIPAL ACT, R.S.O. 1970, c.284

Section 354

This section allows the council of a local municipality to pass by-laws in regard to certain subject matters.

Paragraph 71 of subsection 1 of this section permits a municipality to make regulations for sewage or drainage that may be considered necessary for sanitary purposes.

Paragraph 72 of this same subsection stipulates that by-laws may be passed for establishing, acquiring, operating and maintaining sewage works, including sewers, pumping plants, treatment works and other like works necessary for a sewage system and for regulating the operation and maintenance thereof.

Paragraph 129 of the said subsection empowers a municipality to enact a by-law for prohibiting and regulating the discharge of any gaseous liquid or solid material into land drainage works, private branch drains and connections to any sewer, sewer system or sewage works for the carrying away of domestic sewage or industrial wastes, or both whether connected to a treatment plant or not.

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The legislation cited above enables a municipality to pass by-laws for regulating industrial waste discharges to a storm or a sanitary sewer. These paragraphs are very broad and a municipality's by-law could include provisions which would deal with a particular waste from an industry, and therefore be utilised to pressure a company to pretreat its wastes in order to conform to the by-law.

Section 362

Subsections 16 and 18 of this section allow a municipality to pass a by-law to provide for imposing upon owners and occupants of land who use sewage works a sewage service rate. The rate structure established by the municipality may take into account the various classes of users, the nature, volume and frequency of use and other relevant matters to ensure that the sewage service rates are imposed upon a basis that is equitable and just.

Therefore, a municipality may utilise these subsections to tax an industry at a very high rate, and therefore it would be financially advantageous for the company to install pretreatment facilities.

THE LOCAL IMPROVEMENT ACT, R.S.O. 1970, c.255

A council of a local municipality may undertake as

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a local improvement the construction and enlargement or extension of a sewer including a sewer on each side or on one side only of a street.

Section 4

This section stipulates that a private drain connection shall be specially assessed on the particular lot for which, or in connection with which, it is constructed upon, on the basis of footage of the lots; and the owners of the land do not have the right of petition provided for by section 12.

Therefore, section 4 may be used to force a company or an individual to connect to the sanitary sewage works and therefore prevent the discharge of industrial wastes to a storm sewer. On one occasion a municipality notified the OWRC that two car washes were not prepared to connect to the sanitary sewers. The companies were notified that the discharge of industrial wastes to a storm sewer may amount to a violation of Section 32(1) of The Ontario Water Resources Act. Subsequently, the companies connected to the sanitary sewers. It is submitted that the municipality could have utilised Section 4 of The Local Improvement Act to accomplish its objectives.

THE DRAINAGE ACT, R.S.O. 1970, c.136

This act may be applied in local municipalities where there are no storm or sanitary sewers in some areas.

Section 60

This section stipulates that "Except as authorized by by-law of the initiating municipality, approved by the OWRC, no person shall discharge or deposit, or permit to be discharged or deposited into any drainage works any liquid material or substance other than unpolluted drainage water". A violation of this section is a minimum fine of $10. and a miximum fine of $100.

The above three Acts are only examples of some of the powers a municipality has with regard to controlling pollution. Under The Municipal Act and The Drainage Act the maximum penalty for a violation is $300. and $100. respectively. However, Section 32(1) of The Ontario Water Resources Act provides that anyone who discharges or deposits or permits a discharge or deposit of any material that may impair the quality of the water of the receiving watercourse is liable to a monetary penalty of $5,000. on the first offence, and $10,000. on each subsequent offence. Although the

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degree of proof required to obtain a conviction for a violation of section 32(1) of The OWR Act is more stringent, nevertheless, in many instances it would be more advantageous for the municipality to proceed under the OWRC Act if there is a discharge to a storm sewer or to a local ditch.

Municipal sewer-use by-laws are an attempt to regulate, in as just and as reasonable a manner as possible, the disposal of liquid industrial wastes to municipal sewers. Ideally, this would involve establishing the tolerance limits of the municipal sewerage system, including sewers, pumping stations and treatment works, for all of the existing and potential liquid industrial wastes in the municipality and legislating these tolerance limits in the form of a by-law. Obviously, this is not practical. Tolerance limits for many industrial wastes will vary with the volume and characteristics of other wastes present in the municipal sewage, and it would be impossible to legislate to deal with all of the potential problems in what is essentially a dynamic system.

You are probably familiar with the Model By-law

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which is contained in the publication, "Industrial Pollution Control in Municipalities", this is our attempt to provide a rational basis for the regulation of industrial wastes in municipal sewers. What we have attempted to do, is to provide practical limits for the regulation and control of most of the industrial waste constituents likely to be encountered in a municipal sewerage system. These limits are based on the known toxicity or potential adverse effects of the particular waste constituents, with a substantial safety factor inserted to ensure that the by-law can be universally applied to all municipalities. Herein lies the inherent weakness of the Model By-law.

As has been discussed previously, the effects of many industrial waste constituents on municipal sewerage systems depend upon the nature of the sewerage system. For example, an excessive soluble organic loading, as represented by the BOD analysis, may tend to overload a municipal secondary treatment plant, whereas its effect on a municipal primary treatment plant with settling and sludge digestion facilities only is likely to be minimal. The subsequent effect of this waste on the receiving watercourse after passage through the primary treatment plant may be

undesirable and in itself dictate that the industry responsible clean up, but it is probably unreasonable to insist that industrial wastewaters of this type be treated to a greater extent than municipal sewage discharging to the same watercourse.

Furthermore, the size of the municipal sewerage system influences the degree of effect the particular waste constituent may have. This is largely a function of the dilution available in the sewer system and is quite significant in relation to toxic constituents and to those waste constituents which in excessive amounts may give rise to overloading problems.

We have attempted to overcome these factors to some extent by providing a range of maximum permissible concentrations for the various waste constituents, so that the size of the municipal sewerage system can be taken into account in selecting the specific by-law limit. However, this is only a compromise in relation to discharges to sanitary sewers and, in the case of discharges to municipal storm sewers, it was felt essential that the most stringent regulations be applied in order to protect all classes of receiving watercourses, from small creeks to large lakes and

rivers. In other words, one can apply a rule of thumb, based on the nature and size of the municipal sewerage system, to the selection of limits from the recommended range in the by-law for the regulation of discharges to sanitary sewers, but there is no rule of thumb which can reasonably assess the relative assimilative capacities of natural watercourses and, therefore, the most stringent limits must be applied to the discharges to municipal storm sewers which enventually discharge to a watercourse. This tends to encourage industries to discharge wastewaters to municipal sanitary sewers.

In drafting the by-law, we were faced with the problem of preparing a document which would be legally correct and at the same time, couched in terms that the "non-legal" mind can understand. Unfortunately, in the process we have produced a by-law which contains many technical terms and is at times almost incomprehensible to the "non-technical" layman.

It is in this category that the series of definitions in the first section of the OWRC Model By-law are placed. It is impossible to present this information in any other way and remain legally correct and technically accurate. We are, therefore, frequently called

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upon to explain these definitions to non-technical municipal officials and/or industrialists.

The general discussion on pages 5, 6, 7 and 8 of the brochure also explains many of the technical terms contained in this list of definitions in the by-law. Other definitions such as sewers, sewage, watercourse and Standard Methods are self-explanatory.

The regulations contained in Section 2 of the Model By-law are fairly straightforward and generally follow the principles outlined in the discussion which precedes the by-law. Certain regulations, such as those dealing with matter capable of obstructing the flow in sewers, sewage which may cause a nuisance and sewage containing animal waste, are both general and specific in nature. That is, wastes of the general nature mentioned above are prohibited and specific waste components are also prohibited in the by-law in case it can be argued that they are outside the general definition.

As mentioned previously, the storm sewer regulations are intended primarily to protect the receiving watercourse. Nevertheless, it can be seen that the

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general regulations are the same as those for discharges to sanitary sewers and differ largely in that the storm sewer regulations are more stringent. Therefore, like the sanitary sewer regulations, the protection of the sewer system as well as the receiving watercourse is an integral part of these storm sewer regulations.

Following the enactment of such a by-law, or during the preliminary discussions with interested parties, it may become clear that certain industries, or commercial establishments in the municipality, are unable to meet some of the conditions of the by-law without excessive costs. It is essential that such situations be carefully examined. This is where industrial waste surveys, involving the collection and analysis of waste samples, are of vital importance, both from the point of view of defining the problem and in possible negotiations leading to a special agreement with the industry involving a surcharge.

Section 5 of the Model By-law permits such special agreements and, provided that no adverse effects are likely to result from the discharge of

high strength wastes to the municipal sewerage system such agreements are a reasonable alternative to the complete prohibition of certain industrial wastes in the municipal system or the imposition of undue costs of waste treatment on the industry. This is a difficult judgement to make and may involve a wide variety of considerations. Staff are often called upon to give advice to municipalities in this area and although we will continue to provide this service, it is essential that the municipality collect as much of the relevant data as possible. Surcharges and associated information are the subject of another presentation. Generally, special agreements and surcharges are applicable only to discharges to sanitary sewers, but with the participation of the MOE, this could conceivably be applied to storm sewer discharges.

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SURCHARGE FORMULAE

Once a municipality has decided that combined treatment of municipal and industrial wastes at a common treatment plant is feasible and can be mutually beneficial to both parties and further, having enacted the necessary regulations for control of the industrial wastes discharges in the form of a suitable sewer-use by-law, it then faces the issue of industrial discharges which will exceed the limits set forth in the regulating by-law. The question arises, as to whether the industry should be required to pretreat its wastes to meet the by-law limits or be permitted to discharge its wastes untreated into the municipal system. This presentation deals only with the second consideration whereby an industry is permitted to discharge overstrength wastes to the municipal sewerage system.

Ideally, in most municipalities, all users pay a sewer service charge for the normal services which are provided. Normal conditions can be described as any waste discharge which does not exceed the limits as set out in the sewer-use by-law. Under abnormal conditions, the municipality is burdened with additional costs for treating overstrength industrial wastes. One avenue available to the municipality to recover these additional costs incurred on behalf of the industry

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is to assess an equitable surcharge. The primary purpose of this lecture then, is to outline the more common methods available for surcharging an industry in such a situation.

Before considering the methods whereby a surcharge can be applied, two basic conditions are necessary before an overstrength industrial discharge can be accepted into the municipal sewerage system:

(1) The wastes must be amenable to treatment by the processes utilized at the municipal treatment facility.

(2) There must be sufficient capacity available at the municipal treatment facility to accommodate the additional industrial waste load.

If the foregoing conditions are satisfied, then the municipality is in a position to enter into a special agreement with the industry whereby the industry would be permitted to discharge its overstrength wastes to the municipal sewerage system, up to a specified amount, and the municipality outlines the terms under which it would collect a surcharge for the additional treatment costs which may be incurred.

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The question now arises: How does a municipality go about surcharging overstrength industrial waste discharges? There are many surcharge formulae which can be used but they all basically fall into two definite categories - (1) Flat Rate and (2) Quality - Quantity or Q-Q formulae.

(1) Flat Rate

The Flat Rate Surcharge Formula represents an effort to allocate charges on the basis of some conveniently determined unit. Depending on the municipality and the industry in question, the choice of the unit is limited only by the imagination of the selector. For example, the unit may be a percentage of the water bill, number of employees or a unit of production such as cases of canned goods produced. The general flat rate surcharge formula appears as follows:

$$S = R \times N$$

where:
- S = surcharge in dollars
- R = rate per unit in dollars
- N = number of units

The flat rate formula is simple to administer once the unit and rate have been established. Surcharge costs are simple to calculate and waste sampling is not

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required. Once the unit has been determined, the industry reports the number of units and the charges are computed.

The charges assessed under the flat rate formula are an approximation at best, since they do not take into account the characteristics or the strength of the wastes and these are the parameters which will have the greatest effect on the operation of the treatment facility.

Some examples under the flat rate formula are as follows:

<u>NOTE</u>: all municipalities in the U.S.A.

Case (1) --- 50% of water bill with monthly minimum of $1.00 and maximum of $10.00

Case (2) --- Creameries and laundries - $10.00 per month.

--- Canneries and food processing - $20.00 per month.

--- Other industrial plants - $5.00 per 100 employees per month.

Case (3) --- Dairies - $16.17 per month

--- Creameries - $150.00 per month

--- Metal Plating - $ 50.00 per month

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--- Other industries (no industrial wastes)

- employing up to 10 people
  $1.75 per month
- employing 10-50 people
  $8.33 per month
- employing over 50 people
  $16.67 per month.

(2) Quality-Quantity Formula

The Quality-Quantity Formula is an attempt to assess surcharges on a more equitable basis, since it takes into account both the concentration and volume of the industrial waste discharge. The surcharge imposed under the Q-Q formula is usually calculated on the amount of waste which exceeds that of normal domestic sewage. Generally, the limits specified in the sewer-use by-law are used as the basis upon which to determine the surcharge. Each municipality wishing to use a Q-Q formula must develop its own, although all Q-Q formulae originate from a basic equation which assumes that municipal taxes and/or other means such as a surcharge on the water bill pay for the fixed costs and also for the operating costs to treat a normal strength waste.

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A typical Q-Q formula is as follows:

$$S = 10V\left[b\ (B_W - B_L) + s(S_W - S_L) + g(G_W - G_L)\right]$$

where S = surcharge in dollars

V = volume in gallons

10 = conversion from gallons to pounds

b, s, g = cost in dollars to treat one pound of BOD, suspended solids, grease respectively.

B_W, S_W, G_W = concentration in milligrams per litre of BOD, suspended solids, grease respectively, in the waste.

B_L, S_L, G_L = concentration in milligrams per litre of BOD, suspended solids, grease respectively, permissible in sewer-use by-law.

NOTE: (1) mg/l (milligrams per litre) is equivalent to ppm (parts per million).

(2) any time period may be selected, i.e. day, week, month, quarter-year, half-year, year.

(3) surcharge only applies to those parameters which exceed the by-law limit.

(4) any number or combination of parameters may be used depending on the circumstances, e.g. others which may be considered are phenol and chlorine demand.

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It can be seen from the basic Q-Q formula that a number of variations are possible. For example, some municipalities may wish to include all the parameters, i.e. BOD, suspended solids, grease, phenol and chlorine demand while others may only wish to include BOD and suspended solids. In the case of a municipality which has only primary treatment facilities, it makes sense to consider only suspended solids and chlorine demand since any BOD which is removed is associated with the suspended solids and to some extent, the chlorine treatment. Metro Toronto uses only one parameter to calculate the surcharge. The parameter used may be either BOD, suspended solids, grease or phenols, and is that parameter which exceeds the respective sewer-use by-law limit to the greatest extent. A number of Q-Q formulae used by various municipalities in Canada are given at the end of this paper.

Another common variation of the basic Q-Q formula is to take into account assessment. In this case, the industry is permitted to discharge specified amounts of BOD, suspended solids and/or other paramaters selected in direct proportion to its assessment as compared to the total municipal assessment. In other words, if a particular industry accounted for five

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percent of the total assessment in the municipality, it would be permitted to discharge without incurring a surcharge, up to five percent of the total BOD, suspended solids, etc., loading to the treatment plant. Anything in excess of this amount would be subject to a surcharge.

There are several advantages of employing a Q-Q formula. It is an equitable charge in that the characteristics of the industrial waste and the costs associated with those characteristics are directly taken into account. Another advantage of this type of formula is that ir provides an incentive for industry to reduce the strength and volume of their waste discharge. Experience cited in the literature has shown that a marked reduction in BOD and/or suspended solids is achieved in the first few years that a surcharge is in existence. Although the incentive to reduce BOD and suspended solids remains as long as the surcharge is in effect, the major reduction is achieved in the early years after implementation. A surcharge cause industries immediately to improve their housekeeping procedures and to introduce some pretreatment. Some industries may adopt new processes which produce less waste or which recover wastes. Greater consideration may be

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given by some industries to water re-use. After this initial reduction, however the chief effect of the surcharge is to restrain industries from introducing practices that would greatly increase the waste loadings from their plants.

The chief disadvantage of the Q-Q formula is that the administration of the surcharge is complex. Once introduced, all industrial wastes must be sampled to determine the surcharge for subsequent periods. Another difficulty in developing a Q-Q formula is in determining the cost to be applied in the formula to treat one pound of BOD, suspended solids, etc. The development of these cost figures requires a fairly detailed engineering analysis of the treatment costs at the municipal treatment works.

SUMMARY

In summary, once a municipality has accepted the principle of combined treatment of domestic and industrial wastes and has enacted a sewer-use by-law for control of the wastes, it should then be prepared to consider the implementation of surcharges to be assessed against those industries which discharge wastes exceeding the by-law limits.

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General formulae have been described which can be used to assess a surcharge and it is left to the individual municipality to decide upon which formula will best serve its needs in collecting an equitable surcharge from the industries concerned.

The following are examples of surcharge formulae in force in the various municipalities:

CITY OF KINGSTON - SURCHARGE FORMULA

Quantity Surcharge = (a X G) - (c X A)

where a = cost of pumping one gallon of sewage to WPCP

G = industry's sewage flow in gallons

c = number of gallons per assessment dollar

A = industry assessment

Quality Surcharge = (b X W) - (d X A)

where b = cost of treating one pound of combined load of BOD and SS.

W = industry pollution load of BOD and SS

d = number of pounds of BOD and SS treated per assessment dollar.

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MUNICIPALITY OF METROPOLITAN TORONTO - SURCHARGE FORMULA

Annual surcharge = V x F x G x C

where: Annual surcharge in dollars

V = Volume of annual plant discharge in imperial gallons

F = Factor converting mg/l to pounds per gallon, i.e. $\frac{10}{1,000,000}$

G = Suspended solids, BOD, grease or phenols, whichever is greatest in excess of the respective by-law limits.

C = Cost for treating excessive waste strength in dollars per pound (present cost in Metro Toronto = $0.015 per lb.)

CITY OF CHATHAM - SURCHARGE FORMULA

Annual Surcharge = A(L - F'S) + B (N - F'S)

where:

A = cost in dollars to treat one pound of BOD

B = cost in dollars to treat one pound of SS

L = total annual BOD load from industry

N = total annual SS load from industry

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F' = assessment factor for BOD, which is the total pounds of BOD treated per year divided by the total property and business tax collected in the municipality.
i.e. pounds BOD/dollar of assessment.

F" = assessment factor for suspended solids, which is the total pounds of SS treated per year divided by the total property and business tax collected in the munitipality.
i.e. pounds SS/dollar of assessment.

S = industry's individual property plus business assessment.

CITY OF LONDON - SURCHARGE FORMULA

$$\text{Annual Charge} = x \left[(V_b - (f \times Ai \times 0.07)\right] + y \left[(V_s - (f \times Ai \times 0.07)\right]$$

where: x = cost per pound to treat BOD in dollars.

y = cost per pound to treat suspended solids in dollars.

NOTE: = x and y calculated on both operating costs and debt retirement costs, the total of which is split in half to calculate x and y, respectively.

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V_b = pounds of BOD discharged to sanitary sewer by the industry

V_s = pounds of suspended solids discharged to sanitary sewer by industry.

f = strength assessment factor = 3

= a benefit constant by which the product of pounds of BOD and suspended solids per assessment dollar for domestic sewage and the total assessment for the person or industry to be surcharged is multiplied to achieve a fair and equitable non-surchargeable amount of BOD and suspended solids.

Ai = total property and business assessment for person or industry to be surcharged.

0.07 = pounds of BOD or suspended solids per annum per assessment dollar for domestic sewage.

<u>CITY OF WINNIPEG, MANITOBA - SURCHARGE FORMULA</u>

$$Ri = \left[fs \left(\frac{Si - Sn}{Sn} \right) + fp \left(\frac{Pi - Pn}{Pn} \right) \right] Rn + \left(\frac{Ci - Cn}{Cn} \right) Rc + \left(\frac{Xi - Xn}{} \right) Rx$$

where Ri = surcharge on the industry /1,000 Imperial gallons.

fs = factor derived from cost of reducing solids, in this case (1971) fs = 0.52.

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fp	=	factor derived from costs of reducing BOD, in this case (1971) fp = 0.48.
Si	=	Suspended solids in ppm, in industrial wastes as determined from the composite samples collected from the industry.
Pi	=	Biochemical Oxygen Demand in ppm in the industrial wastes.
Ci	=	Chlorine demand in ppm in the industrial wastes.
Xi	=	Substances requiring additional treatment in ppm in the industrial wastes. Presently this is grease or other soluble substances.
Sn	=	Suspended solids in ppm in the sewage serving as a base or normal. At the present time, this is 350 ppm.
Pn	=	BOD in ppm in the sewage serving as a base or normal and this is 300 ppm.
Cn	=	Chlorine demand in ppm in the sewage serving as a base or normal.
Xn	=	Substances requiring additional treatment in ppm in sewage serving as a base or normal and is 100 ppm.
Rn	=	Unit charge based on the cost of treating normal sewage, the Rn value is 5.88 cent/unit of 1,000 Imperial Gallons.
Rc	=	Unit charge based on the cost of required chlorine which is 1.34 cents per unit of 1,000 Imperial Gallons.
Rx	=	Unit charge based on costs of treating any substances requiring additional treatment. Presently this is for grease (ether soluble material) and the Rx value per unit is 4.00 cents/1,000 Imperial Gallons.

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APPLICATION

OF THE COURSE MATERIAL

TO THE

CONTROL OF INDUSTRIAL WASTES

Much excellent material has been presented in the course and this paper will be an attempt to draw together the various aspects of the individual control measures and to show how they should be integrated into an effective industrial waste control programme.

ROLE OF THE MUNICIPAL COUNCIL

Of fundamental importance to the development of any enforcement programme, is the realization and acceptance of the need for a programme by the Council of the Municipality.

The topic of By-Laws has been covered in other presentations and it will suffice therefore to re-iterate that the Municipal Council must accept the fact that if the Municipality has by-laws, it must have controls on these by-laws, and that the control of a sewer-use by-law requires an extraordinary amount of attention by the Council.

Let it be assumed, therefore, that the Municipality has a suitable sewer-use by-law and is serious about establishing an effective industrial waste control programme.

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Step 1 on the part of the Municipal Council is to become sufficiently familiar with the needs of the Municipality to make intelligent decisions on the formation of the control programme. This familiarization of Council can be augmented by a briefing from the technical head of the Municipality. The material presented in this brief to Council should include not only the number of industries but the number with liquid wastes, and the existing capability of the Municipality to enforce the sewer-use by-law. Benefits to the Municipality such as increased sewer life, revenue from surcharges and increased sewer and treatment plant capacity from the rerouting of clean flows, should be stressed. The Technical Head should submit recommendations in this brief on what he feels is required for the establishment of a satisfactory programme. He should include a proposed budget for staff, equipment, etc. The Council may wish to discuss the recommendations of the technical head with representatives of the Provincial Government and other Municipalities prior to deciding on the policy for the Municipality. When the Council has decided the policy for the programme, it should be involved only in periodic reviews of the programme probably annually, and in cases requiring policy revisions. The Council should not become involved in the

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day-to-day workings of the programme. If a Council member is approached by a local industrialist for a favour, he should be referred to the technical staff. Too often good control programmes have become bogged down because of the involvement of Council members in technical matters.

ROLE OF THE TECHNICAL HEAD OF A MUNICIPALITY

In order for the Technical Head to prepare the brief that has previously been suggested Town Council would require, it is necessary for him to collect the following data:

- types of industries
- types of industries with liquid wastes
- those on sanitary sewers
- those on storm sewers
- those that information is available on
- problems that he is aware of
- staff now working in this area
- capability within his own staff to carry out enforcement work
- equipment that is available (samplers, flow measurement equipment, etc.)
- sewer diagrams and location of industrial discharges (if available)
- laboratory facilities available

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- cost of laboratory analysis at an outside lab

From these data, the Technical Head must decide what is needed to establish a control programme. The most important need is competent staff. It has been the experience of the Ministry that one full time person should be hired when a municipality reaches 20 - 25,000 population, providing that there is an average density of industry in the municipality. Prior to reaching this size, the municipality should have a qualified person working on a part-time basis. This person could also assist in other municipal work such as the operation of the sewage treatment plant. He should, however, be qualified and trained for the role of enforcer even if he is only working at it on a part-time basis. In Municipalities of over 25,000 persons it is probable that one enforcer should be added for every 50,000 of population. Many factors such as concentration of industry in the Municipality, complexity of industrial operations, assistance from other Municipal departments, amount of lab work involved, availability of mechanical equipment (samplers, etc.) would affect this guideline, but the minimum required coverage should be possible with this arrangement. Based on the above, the Technical Head should be able to decide how many people he requires.

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Also to be included in the brief to Council is the type of person needed. Is there presently someone on staff who is capable and may be transferred to the new position or must someone be hired? In order to determine the requirements in this area, the Technical Head must decide on the qualifications needed by the staff of the enforcement group. The experience of this Branch of the Ministry suggests that the following qualities be considered for the staff of the enforcement group: (1) character, (2) academic experience, and (3) work experience.

(1) He should be a sincere, mature individual with good common sense and capable of rational, unemotional action.

(2) The person should be a high school graduate with a thorough knowledge of chemistry and preferably a graduate of a technical school where the theoretical and practical aspects of chemistry are stressed.

(3) He should have enough related industrial experience to enable him either to choose an independent laboratory and know which analyses to

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request, or to set up a municipal laboratory and conduct routine tests (BOD, COD, solids, pH), whichever is the wish of the municipality.

When there is to be only one person on staff, it is essential that one with at least the above qualities be hired. For additions to the staff, however, persons strong in specific areas, such as laboratory analyses, industrial processes, may be considered.

The Technical Head should recommend to Council that a minimum budget for staff, equipment and outside laboratory services be provided initially, since the needs of the programme may change as it develops. It should be pointed out that initially it is advisable to have any samples resulting from the enforcement programme submitted to an outside laboratory for analysis rather than to set up an individual lab as it is most difficult to predict the needs of the municipality in this area.

After the submission of this brief to the Municipal Council and the establishment of policy by Council, it must be assumed that the Technical Head has the authorization to acquire whatever staff, equipment and services he needs to implement the control programme. As important

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as hiring staff and obtaining the necessary equipment, is the drafting of job descriptions and the training of the staff. As the Technical Head is probably not too familiar with the details of industrial wastes surveys, etc., he should provide only general guidelines for the enforcement group and refer them to literature (and courses such as this) for specific facets of the programme. It is important, however, that the Technical Head require the group to provide him with periodic status reports (preferably monthly), and to keep him fully informed on those industries not complying with the terms of the sewer-use by-law. The latter point is extremely important as it allows him to decide on a course of action with the problem industries and also to alert the council and/or the Provincial Government if it appears that an industry is going to appeal for special consideration through non-routine channels. The Technical Head should not become more intimately involved, however, so that the enforcement group may carry out all aspects of the routine enforcement programme thus attain a necessary amount of job satisfaction.

ROLE OF THE ENFORCEMENT GROUP

The enforcement group should proceed to carry out

surveys at each industry in the Municipality. The starting point for these surveys should be a list of all the industries, along with water consumption figures, types of processing, points of waste discharge and any other related information which is available. This information should be reviewed with whoever has been previously involved, such as representatives of the Industrial Wastes Branch of the Ministry of the Environment, to try to determine the priorities in setting up the programme. Once these have been established, a survey or two should be carried out with the assistance of someone with related experience. In this way, the members of the enforcement group will become experienced in carrying out a survey and will thus be able to obtain the necessary information from each industry and prepare a report on each. It is only with this initial detailed information on each industry that an inventory can be built up to allow institution of an effective programme.

From the results of the initial survey at each industry, those in violation of the terms of the by-law can be discovered. The data for each of those in violation should be passed on to the Technical Head with any pertinent comments and recommendations. Action of

the industry in one of three ways may then be required:

(1) Pretreatment of wastes to comply with by-law limits,

(2) Payment of a surcharge according to the formula in the by-law, or

(3) If the wastes cannot be accommodated at the sewage treatment plant and a refusal to pretreat further is encountered, the industry should be asked to cut back or cease operations. Punitive measures may be taken according to the terms of the by-law, but it must be noted that these measures are not a solution in themselves and are useful only as an incentive to industry to co-operate.

Hopefully, industry will co-operate, but the municipality must be prepared to take a firm stand if required.

If the industry is in compliance with the terms of the sewer-use by-law, a routine monitoring programme may be set up. This would consist of checks approximately twice yearly for those well within the by-law to determine if production and/or methods of processing and disposal of wastes have changed, but for those industries approaching the limits of the by-law, more

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regular checking may be required. Where an agreement is in effect, surveillance according to the terms of the contract must be carried out. In the cases where an industry is violating the terms of the by-law, constant attention must be maintained and this may involve sampling monthly, weekly or even daily, depending upon the need for detailed information by those negotiating with the industry.

Location of Enforcement Group

The ideal location for the enforcement group is at the sewage treatment plant. Here, upset conditions can be noted first-hand and there is no substitute for this in the detection and pin-pointing of a problem. For example, a person becomes familiar with the types of problems to be anticipated at the sewage treatment plant and by actually observing the effect on the operation of the plant, he is in the best position to determine the source of the problem. If he is located elsewhere and must drive to the sewage treatment plant to observe the problem, he is at a disadvantage in terms of correcting the problem effectively and quickly. Also, during inactive periods he may assist the treatment plant staff but at no time should his primary function of by-law enforcer be forgotten.

Too often, in situations to date, has the enforcer become so involved in the operation of the sewage plant that the duties of enforcing the by-law have been neglected.

The enforcement group must be kept informed on new industry wishing to locate in the municipality. Prior to the issuing of a building permit, a detailed application form should be submitted by the company for the approval of the enforcer and his supervisors. If there is any question regarding the acceptability of the wastes from the industry, the Industrial Wastes Branch of the Ministry should be asked for comments. It is imperative that written facts be obtained from each industry on the pertinent aspects of their operation (waste flow and characteristics) so that if the company alters production or processing methods and causes problems at the sewage treatment plant, it may be held responsible by the enforcement group on the basis of the change in written conditions. Otherwise, it is very difficult to hold any industry responsible for operating alterations.

SUMMARY

When a municipality has a sewer system, it must have

a by-law containing limits on the characteristics and ideally quantities of wastes acceptable for discharge to the system. Equally important is the enforcement of the by-law. It is the municipality's responsibility to establish a competent enforcement group to ensure that the terms of the by-law are being met. It is felt that if the Administrative and Technical Heads of the Municipality, and the enforcement group, carry out their duties as outlined in this paper, the enforcement programme will be effective.

INDUSTRIAL WASTES CONTROL

IN

THE CITY OF WINDSOR

INTRODUCTION

As an introduction, the history of industrial pollution control activities in the City of Windsor should be discussed briefly:

(1) Early in 1968, the Ontario Water Resources Commission, District Engineer and his staff, conducted an industrial waste survey of Windsor and found:

(a) many plants were discharging directly into watercourses and storm drains. In many cases the waste failed to meet O.W.R.C.'s effluent quality objectives.

(b) high concentrations of toxic materials were discharged without pre-treatment.

(c) the industrial contribution was estimated to be about 38% of the hydraulic capacity of the municipal sanitary system. This waste contained approximately 33% of the BOD and 14% of the suspended solids load.

(2) As a result of this survey, the Ontario Water Resources Commission recommended that:-

(a) The City enact a sewer-use by-law to control and regulate the discharge of liquid waste that might adversely affect the municipal sewage collection system and interfere with the proper operation of the treatment works. The by-law is based on the O.W.R.C.'s model by-law as found in the

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brochure "Industrial Pollution Control in Municipalities."

(b) The City acquire trained technical personnel to police and enforce the terms of the by-law by collecting the necessary effluent samples and carrying out periodic industrial waste surveys.

(c) industrial waste discharges to a watercourse, storm sewer, ditch, will be controlled by the Ontario Water Resources Commission. Industry in this category will be under the jurisdiction of the Ontario Water Resources Commission and the necessary treatment facilities will be approved and monitored by the personnel reporting to the District Engineer. Since the big automotive complexes discharge to watercourses directly, their treatment facilities will not be discussed.

To comply with the Ontario Water Resources Commission recommendations, the City officials prepared a sewer-use by-law which was finalized in May 1968, and became effective September 1, 1969.

Incorporated into the construction of a new 24 m.g.d. primary treatment sewage plant was a laboratory which serves as the command centre for the control of industrial waste and sewage treatment plant operation.

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The Commissioner of Works and Director of Sewage Treatment chose to employ a chemist, a laboratory foreman and two technicians as the enforcing body. The chemist reports to the Director of Sewage Treatment, who in turn, reports to the Commissioner of Works.

The completion of the laboratory and staffing of personnel were achieved in February, 1970. The Regional Engineer and his staff gave our Branch invaluable assistance and guidance in the initial stages of our pollution control program.

DISPOSAL OF CONCENTRATED WASTES

The Ontario Water Resources Commission survey showed that in addition to the wastes disposed of through the sewer system, there were 12,000 gallons per day of strong liquid wastes of industrial origin which were hauled to the municipal landfill site and dumped into an industrial lagoon. The wastes were found seeping into drainage ditches and watercourses and thereby polluting the receiving streams. City Council authorized the Industrial Research Institute of the University of Windsor to conduct a survey to more accurately determine the type and quantitiy of liquid industrial wastes generated by industry, so that a more satisfactory method of disposal could

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be adopted. The survey revealed that a total of 3,320 tons per year of flammable liquid wastes were taken to the lagoon at the sanitary landfill site and a total of 17 tons per year of inorganic compounds such as acids, cyanides, chromates and chlorides were disposed of in a similar manner. Most of the soluble inorganics were disposed of by way of floor drains and sewers.

Consequently, by mid-1970, more than a million gallons of waste had accumulated in the industrial lagoon. Before the lagoon could be phased out, the dam wall broke spilling most of the contents into a drainage ditch and onto the surrounding area. The spilled oil and wastes were dammed before reaching the River and had to be hauled back to the lagoon, which was repaired and the dam walls made impervious with layers of clay. City Council immediately passed a resolution to close the lagoon to liquid industrial waste on a month's notice. In the Fall of 1970, the oil was removed by private contractor and hauled to Sarnia for ultimate disposal. The lagoon was backfilled to prevent odour problems from developing. Then the problem arose on how to dispose of the generated liquid waste in the future. Windsor was fortunate to have Goodfellow Enterprises

of Sarnia establish a satellite station in Windsor for the acceptance of industrial waste. Large industrial concerns constructed their own incinerators for the combustion of flammable liquid wastes. Large volumes of pickling acids, oily wastes, etc., are hauled to Sarnia directly; small volumes are received in storage tanks at the Goodfellow Satellite Station but these too are ultimately hauled to Sarnia for disposal.

RAILWAY YARDS

Windsor has several railway yards. One of them, a fuelling depot for the Southwestern region, became a serious problem when the company replaced steam engines with diesel engines in the mid-1950's. Diesel fuel is received and stored in a 175,000 gallon storage tank. During refuelling, copious volumes of diesel fuel were spilled on the ground due to malfunctioning dispensing valves and carelessness of fuelling personnel. The spilled fuel oil percolated through the soil and entered the City's sewer system causing hazardous conditions. The obnoxious fuel oil fumes entered nearby dwellings via sewer laterals causing unpleasant living conditions and thereby generating innumerable complaints. Before the industrial pollution control division came into existence, the Fire Prevention Bureau contacted the management of the railway regarding the spillage of

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fuel oil, but progress in removing the problem was slow, to say the least. Early in 1970, representatives from the City of Windsor, the Ontario Water Resources Commission and the Ontario Department of Energy and Resources, placed considerable pressure on the management of the railroad to bring the problem under control. It should be pointed out that by 1970 the Bell Telephone manholes, as well as other sumps in the area, were filled with a water/oil mixture which contained approximately 50% diesel oil. Although the manholes were pumped out regularly, the terrain was saturated with oil and the manholes refilled almost as fast as they could be pumped out.

The Railway then made trenches 3 feet wide by 8 feet deep at four critical locations and pumped constantly for two weeks until the oil draining into these trenches ceased to flow. During this time, approximately 48,000 gallons of fuel oil were pumped out of the trenches. The cause of the oil loss was traced to a hole in the four-inch diameter fuel pipe from the main storage tank. Apparently, when the line was originally installed, the excavation was backfilled with cinders. The cinders caused pitting and corrosion of the pipe.

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To rectify the situation, the Railroad has installed

(a) two three-stage oil separators at strategic locations to intercept the discharge from two laterals which could be contaminated with fuel oil. The oil accumulations are pumped into an above-ground settling tank. When separation has taken place, the water is run off into the first stage of the oil separator. The remaining oil residue is transferred to above-ground waste oil storage tanks.

(b) in the immediate area of the fuel dispenser, concrete drip trays were installed to cover an area of approximately 2,000 square feet. Any spillage during fuelling is trapped by the trays. The drip tray catchment area drains into a 5,000 gallon underground holding tank. The contents of the holding tank are transferred to the above-ground settling tank for the removal of oil.

(c) to prevent further leakage from the fuel carrier line, the line was replaced with a new C.S.A. approved pipe. Furthermore, the pipe will be encased in a concrete trench which drains into a 5,000 gallon underground holding tank. The trench will have a removable cover to facilitate periodic inspections. Should leaks develop they can be readily stopped by locating the source and repairing the defective piece of pipe.

The oil concentration in the railway's discharge lateral before oil interception was 3,700 ppm. Recent samples contained from 7 to 37 ppm of oil, which corresponds to a 99% reduction. The abatement equipment improved the water quality entering the city sewer and since the pollution control devices became effective, the residents in the area have not found it necessary to complain about fuel oil fumes entering their dwellings.

METAL WORKING PLANTS

The city of Windsor had eight plants in this category. The size varied considerably; the smallest having a daily water consumption of 3,000 gallons, whereas the largest used approximately 560,000 gallons. The total water consumption amounted to 1,500,000 gallons per day.

Three of the eight terminated operations for one reason or another, but generally speaking it was due to financial problems.

Before the city sewer-use by-law became effective, approximately 8,900 gallons per month of pickle liquor without pre-treatment were discharged into the city sewers. Some of the receiving sewers in the area of the industries were concrete and needless to say, the sewers corroded away over a period of time. In addition

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to acidic discharges, approximately 4,400 gallons of caustic solution varying in strength from 10 - 25% were dumped per month. The monthly soluble oil discharged was approximately 1,200 gallons, not including the 430 gallons of solvents such as methylchloride, varsol, etc.

Monthly discharges from paint booth wash tanks containing paint sludges amounted to 11,000 gallons per month.

In many cases, the continuous rinse after acid pickling had an unacceptable pH value of less than 5.5.

Since the enforcement of the sewer-use by-law, the concentrated pickling acids and caustic solutions are neutralized at the plant with the appropriate reagent and then given time for the sludge to separate before the clear neutralized supernatant is drained into the city sewer.

Oil pollution was one of the major problems encountered in the metal working industry. One stamping company is presently installing a $300,000 two-stage chemical treatment process for the removal

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of oily material from the liquid process waste. Most industries in this category have chosen to handle concentrated waste materials by having a local contractor remove the waste and dispose of it by acceptable methods. Cutting and lubricating oils are hauled away by private concerns for disposal by incineration. Paint wash water is generally treated with a chemical such as "Sno-Flake 13-P" which causes paint sludge to coagulate and float. It is then skimmed off and placed into 45-gallon barrels for disposal by incineration, or it is buried in a landfill site while the liquid is allowed to drain into the city sewers.

ELECTROPLATING

Ten industries in this category were discharging their liquid waste into the combined sewer system. The smallest plating shop used approximately 8,000 gallons of water per day and the largest approximately 400,000 gallons per day.

Before treatment was required, the discharges consisted of batch dumps of acids, caustic and electro cleaners, toxic chemicals such as chromium, copper, nickel, zinc, cadmium and cyanide.

The total waste loading per day was estimated to

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consist of 142 lbs. of chromium, 50 pounds of zinc, 41 pounds of nickel, 26 pounds of cyanide, 11 pounds of copper and approximately 100 gallons of oil from the wash solutions.

As pre-treatment became mandatory, four of the plating companies elected to close their plants rather than to install acceptable pre-treatment facilities.

The total water consumption of the companies now operating is 210,000 gallons per day. The total loading of the sewage system is approximately 17 pounds of chromium, 9 pounds of zinc, 4 pounds of cyanide, 3 pounds of nickel and 1 pound of copper. Continuous rinses are neutralized before they are discharged into the city sewers.

The following are the methods of treatment for chromium and cyanide at these industries:

(a) Chromium

Generally the hexavalent chromium is reduced to Cr^{3+} at pH of 2 by the addition of sodium metabisulfite. The reduced chromium is then precipitated in alkaline medium.

One industry used the Lancy Integrated Chromium

Treatment System. This is a closed loop system employing sodium hydrosulfite in alkaline medium for the reduction and precipitation of hexavalent chromium. This system was checked out recently. The rinse following the chrome treatment tank had less than one part per million of chromium (before dilution with other flows). This we found very satisfactory.

One other major chrome plater is presently installing a Corning Chromic acid recovery unit, at a cost of approximately $50,000 for equipment only. In the interim the metabisulfite reduction and alkaline precipitation method is used.

(b) Cyanide

Only three of the six platers use cyanide-metal baths for electroplating. Two use the chlorination process at elevated pH level for the destruction of the cyanide. Spot checks on the industries showed acceptable levels of cyanide in the effluent.

One industry uses the Pfaudler Cyanide Distillation System. This is a closed loop system rated at 180 gallons per hour. The condensate is returned to the counter-current cyanide rinse tank while the concentrated cyanide solution is pumped back into

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the plating bath. This system was found to work satisfactorily, if provision is made to treat the Pfaudler blow-down which is high in cyanide and metal.

DISPOSAL OF SLUDGES

The dewatering of metallic sludges poses a serious problem to the plating industry. Three industries have installed pressure filters but in most cases have found them troublesome, yielding poor quality effluent. Most platers prefer to allow sludges to accumulate in holding tanks. After a 16 - 24 hour period of quiescence the supernatant is drained off and the remaining sludge is removed by a local contractor. This avoids the initial capital expenditure of dewatering equipment for the small shops which do not have technical expertise in waste treatment.

DAIRY PROCESSING

Four dairies and one cheese manufacturing firm were operating in Windsor just prior to the initiation of the industrial pollution control program. One major dairy closed its doors due to antiquated plant facilities.

All except one dairy are subsidiaries of amalgamated complexes and a strong tendency toward product

specialization in the plants exists. For example, some dairies produced the whole spectrum of dairy products several years ago, but lately have limited their production to one or two products. The other products are obtained from subsidiaries located elsewhere.

The total milk consumption by all firms amounts to 600,000 pounds per day. The total waste water generated is approximately 314,000 gallons per day carrying a waste load of 3,510 pounds of BOD and 1,205 pounds of suspended solids.

Generally the major sources of waste are from the cheese manufacturing and milk processing departments. Whey having a BOD of 35,000 mg/l generally constitutes one-third of the total loading.

Dairies were asked to dispose of waste milk and by-products by other means than the floor drains. Most were successful in getting local farmers to use the waste milk products for pig feed. One dairy was found to very carefully collect the drippings and initial rinses in pails and tanks in the receiving department and then to dump the accumulated product down the drain. This procedure has been changed to

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having the accumulated products picked up by the same farmer who uses the returned and spoiled milk for animal food.

By removing the whey and collected drippings from the sewer system, the waste loading in BOD and suspended solids was reduced by 20% and 16% respectively.

Bottle washing solutions have a pH in excess of 9.5 and before batch dumps take place, the wash solutions are neutralized with inhibited muriatic acid.

We have found good housekeeping procedures to be one of the most important prerequisites for lowering the waste loading from the dairy industry.

FOOD PROCESSING

The two main industries in this category produce anything from canned goods and TV dinners to various fruit juices and fruit salads.

The one producing canned goods uses approximately 200,000 gallons of water per day and generates approximately 1,200 pounds of BOD, 940 pounds suspended solids and 390 pounds of ether solubles.

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To reduce the loading to the sewer, improved housekeeping practices were adopted. Vegetable trimmings, droppings from the bean sprout processing areas are collected in crates and used for animal feed. To reduce BOD and fats, a larger grease interceptor had to be installed and maintained on a daily basis. The removed grease is placed in plastic bags and buried at the sanitary landfill. Spent frying oil is stored in a holding tank and is picked up by private contractor.

The fruit juice and salad manufacturer processed approximately 12,000 pounds of citrus fruit daily, generating a suspended solids load of 3,000 pounds per day. Initially the fruit peels, rag and seed were sluiced and washed down the floor drain. At the sewage treatment plant, problems with sludge handling were encountered and the industry was asked to remove the solid waste from the sewage. Consequently, the waste from the FMC (Food Machinery Citrus Extractor) is collected in large disposal bins. The daily accumulations are trucked to the sanitary landfill for disposal. By making this change, the industry reduced its suspended solids loading by 99% and BOD loading by approximately 40%, and no further problems were experienced at the sewage

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treatment plant.

MEAT PACKING

The major industry in this category employs 138 people, while the three other small packers and sausage manufacturers employ collectively 25 people. The daily total waste loading to the sanitary sewers is 2,130 pounds of BOD, 1,670 pounds suspended solids, and 900 pounds of ether solubles or grease. The total daily water consumption is 226,000 gallons.

The major packing company has complete facilities for slaughtering and processing. Approximately 1,000 hogs and 400 cattle are slaughtered per week. In-plant controls for the removal of non-saleable products consist of the following:

(a) manure is collected from all areas on a dump truck and hauled to the sanitary landfill.

(b) blood from the hog and cattle killing floors drains into boilers where it is dehydrated into a powdery product which is sold to animal feed manufacturers.

(c) casing slimes from the stripping operation, as well as bones, condemned carcasses etc., are collected in a large tank.

Batch lots of the collected material are processed

in a vacuum cooker into a semi-liquid mass which is centrifuged for the separation of liquid from solids. The liquid is pumped into a basin for the recovery of floatable fat, which is skimmed off, transferred to storage tanks and sold to soap manufacturers. The solids are purchased by animal feed producers. Waste water from the washing of carcasses, rendering and processing departments does not receive adequate pre-treatment and consequently the plant discharge is high in BOD, suspended solids and ether solubles. To encourage the industry to adopt tighter in-plant controls and install more pre-treatment equipment, the city is in the process of passing a surcharge by-law whereby the industry will be asked to pay for the treatment of the excess loading to the sewage plant.

The small establishments do not have any pre-treatment facilities. The waste water passes through a three-stage grease interceptor for the removal of solids and grease. As long as the separators are pumped out routinely, they are effective, yielding an acceptable discharge.

BREWERIES AND DISTILLERIES

The breweries have closed their operating plants in Windsor. The distillery, one of the major industries

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and employers in the city, has just recently completed an expansion and modernization program. Included in the expansion was a detailed study of the sewers and waste loading at the point of discharge. Consequently, the storm water and cooling water were segregated from the sanitary and process waste. While the former is now discharged into the Detroit River, the latter is directed to the sanitary sewer for treatment at the sewage plant.

Stringent in-plant controls of all potential sources of waste make it feasible for the company to discharge an acceptable effluent.

A recent survey of the processes showed an average daily discharge of 835,000 imperial gallons and a waste loading of 1,510 pounds of BOD and 670 pounds of suspended solids. Both are within acceptable limits of the sewer-use by-law.

INSPECTION AND INVESTIGATION

The Industrial Pollution Control Group has a panel truck equipped with small tools, sampling bottles, flashlights, traffic cones and squeeze left, squeeze right signs. For routine monitoring and survey work portable recording pH meters are used along with portable automatic samplers. We have found the Markland

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sampler which is energized by a separate patented transistorized circuitry very satisfactory. Samples can be collected at desired intervals from 5 to 60 minutes. To collect samples, the transistorized timing device activates a three-way solenoid valve which opens and allows the compressed air from an air cylinder to enter the Markland sampler and thereby pushes the collected liquid into the sampling container.

A set of rechargeable alkali-mercury batteries are used in the sampler. Since the electrical mechanisms draw only 0.7 milliamps per sample taken, the batteries need to be recharged only after four weeks of constant use. The nickel cadmium cells in the portable recording pH meter provide for approximately 40 hours of continuous pH recordings. The unit has a built-in charger which fully recharges the battery within 10 hours. The instrument can also be operated coninuously on power lines, if desired.

Surveys are generally conducted in the following manner:

The Director of Sewage Treatment and the Chemist contact, at the managerial level, the industry to be surveyed and arrange for a meeting to discuss plant processes, sources of liquid waste and locations of

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sampling points. At some later date, the industrial pollution control group performs a survey by collecting samples from the individual processes and from the plant's discharge lateral. Sampling periods extend over several days of operation covering all shifts. The collected samples are analyzed in the laboratory according to official monographs such as Standard Methods.

For BOD determinations a YSI dissolved oxygen meter is used to read the dissolved oxygen concentration on days one (1) and five (5) respectively. Heavy metals concentrations are determined by using a Unicam 90 Atomic Absorption Spectrophotometer.

The analytical data is then compiled into a report which is submitted to the chief officer of the company. Generally, the Director and the Chemist discuss the submitted report with the company executives and, where necessary, request a treatment proposal and completion date for a pretreatment facility. Periodic contacts are made with the company to assure that progress is being made at a reasonable rate. Most industries have co-operated and the completion dates of the pretreatment facilities have been only slightly delayed. In some cases where extreme tardiness is

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evident, the company officials are asked to meet with the Commissioner of Public Works to explain the lack of progress. At these meetings the company officials are also informed of the penal action that may be taken against the company if the abatement equipment is not completed at a mutually acceptable date. Although court action was taken against one company for not meeting the city's requirements regarding discharges of industrial waste, the charges were dropped when the company met the Sewer-use By-law requirements several days later. Once abatement equipment has been installed, periodic checks are made on the effluent entering the city sewer. These checks generally cover three to four days of continuous pH recordings and sampling programs over 24-hour periods.

SPILL TRACING

To trace industrial spills the following equipment is considered necessary:

(a) complete sewer atlases which show the trunk and subtrunk sewers and all receiving sewers;

(b) accessible means of transportation complete with pick, hammer, and flashlights, and sampling containers;

(c) camera with flash unit. "One picture tells more than one thousand words" is a saying which we found to be true. For this reason we use a Kodak Instamatic 314

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and have found it easy to handle. The pictures are usually clear and give pertinent information especially when colour film is used;

(d) means of communication with base and other city forces. Our panel truck, as are other city vehicles, is radio-equipped and therefore contact can be readily made with the laboratory staff and other supervisory personnel in cases where assistance is needed.

Generally small spills are difficult to trace to the source due to the lag time between discharge and detection at the sewage plant. Usually two to four hours lapse from discharge to detection. When the batch dump requires only a few minutes to take place, it is difficult to trace it to the source. However, if such discharges occur repeatedly, then the industries which are suspected are monitored during the period when the discharge is expected. Usually after several attempts the offender is discovered. Large spills are usually reported by the company before they reach the sewage treatment plant and investigations are undertaken.

CONCLUSION

The city administration adopted the philosophy in the matter of pollution control of working with

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the individual industries to elicit the cooperation of the executives rather than imposing wide-spread legal action. Meaningful dialogues concerning survey results and necessary pre-treatment facilities took place which produced in most cases very satisfactory results.

The most serious problems of acid, alkali and toxic chemical discharges have been brought under control and the receiving sewers are not now exposed to corrosive chemicals and the receiving streams are protected from toxic materials.

The total water consumption of the industries discussed before pollution control equipment was installed was 4,700,000 gallons per day. Since then, the water consumption has been reduced by approximately 47%. The corresponding BOD, suspended solids and ether solubles loadings to the sewerage system have been reduced by 27%, 28% and 37% respectively. The electroplaters have installed pre-treatment facilities and thereby have reduced the heavy metals and toxic waste loading by 80%. We expect the removal efficiencies to increase in this category as more experience and expertise are acquired by the plating industry.

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Now that the major sources of pollution are under control more time is available to investigate the discharges of the smaller commercial establishments, such as service stations, garages, car washes, laundries and bulk storage facilities.

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